REPORT

OF THE

COMMITTEE ON

DISINFECTANTS

OF THE

American Public Health Association.

1885.

COMMITTEE:

GEORGE M. STERNBERG, M. D., Surgeon U. S. Army;
Fellow by Courtesy in Johns Hopkins University.

JOSEPH H. RAYMOND, M. D,
Commissioner of Health of the City of Brooklyn, N. Y.

CHARLES SMART, M. D.,
Surgeon U. S. A., Member National Board of Health.

VICTOR C. VAUGHAN, M.D., Ph.D.,
Member Michigan State Board of Health.

A. R LEEDS, M. D.,
Member New Jersey State Board of Health.

W. H. WATKINS, M. D.,
Medical Director of the Auxiliary Sanitary Association of New Orleans.

GEORGE H. ROHÉ, M. D., Baltimore.

BALTIMORE:
PRINTED FOR THE COMMITTEE.
1885.

TABLE OF CONTENTS.

INTRODUCTORY.

GENERAL REPORT OF THE SECRETARY.

At the last annual meeting of the American Public Health Association held in St. Louis, Mo., October, 14–17, 1884, the following resolution was offered by Dr. James F. Hibberd, of Indiana, referred to the Executive Committee, and, after a favorable report by that Committee, unanimously adopted by the Association :

WHEREAS, It is important equally for practitioners of medicine, for boards or health, and for the general public, that the highest attainments of science in this department of sanitation should be formulated for easy reference by all who need it for practical application, and especially is this desirable in view of the probable visitation of cholera in the near future ; therefore be it

Resolved, By the AMERICAN PUBLIC HEALTH ASSOCIATION, That a Committee be appointed to examine the subject of disinfectants, antiseptics and germicides in their relations to preventive medicine and sanitation, and that said Committee formulate a table of these agents for the information of those interested, the agents to be classified, so far as may be deemed advisable, according to their specific virtues, facility of application, and economy of use.

In accordance with this resolution, the following Committee was appointed by the President of the Association:

Major George M. Sternberg, Surgeon U. S. Army, Fellow by Courtesy in the Johns Hopkins University, Baltimore ; Dr. Joseph H. Raymond, Professor of Physiology and Sanitary Science in Long Island College Hospital, and Health Commissioner of the City of Brooklyn ; Dr. Victor C. Vaughan, Professor of Physiological Chemistry in the University of Michigan, and Member of the Michigan State Board of Health ; Major Charles Smart, Surgeon U. S. Army, and Member of the National Board of Health ; Dr. W. H. Watkins, Medical Director of the

Auxiliary Sanitary Association of New Orleans; Dr. Albert R. Leeds, Professor of Chemistry in Stevens' Institute of Technology, and Member of the New Jersey State Board of Health: and Dr. George H. Rohé, Professor of Hygiene in the College of Physicians and Surgeons, Baltimore.

The Committee met immediately after appointment and organized by the election of Dr. Sternberg as Chairman, and Dr. Rohé as Secretary.

In order to be enabled to make an extended experimental research, the Committee, after consultation, decided to appeal to Municipal and State Boards of Health, and to other sanitary organizations for financial aid. Responses to this appeal were encouraging, and a statement of receipts and disbursements on account of this work is appended to this report.

At a meeting held in Baltimore on November 20, 1884, the Committee was divided into two sub-committees, one, consisting of Drs. Sternberg, Smart and Rohé, to examine the literature of disinfectants, and abstract and tabulate the results, and to investigate in an exact manner in the laboratory the relative germicidal value of the various substances used as disinfectants. The latter part of the inquiry was exclusively under the direction of Dr. Sternberg, the Chairman of the Committee, who was granted exceptional facilities for carrying on this work in the biological laboratory of the Johns Hopkins University. The Committee would here take occasion to express to the Trustees of the University its high appreciation of the courtesy and aid extended by them while these investigations were in progress.

The second sub-committee consisting of Professors Raymond, Vaughan and Leeds, and Dr. Watkins was appointed especially to investigate the practical application of such disinfectants as are found efficient, upon a large scale, their cost, methods of use, chemical relations, effects upon furniture or fabrics, or their possibly poisonous effects upon human beings or animals.

Reports and papers from members of both of these

Committees will be found under the heading "Experimental Data" in the body of this report.

The therapeutic value of the various substances investigated, does not properly come within the purview of the Committee, and has consequently received no attention.

At the Conference of State Boards of Health, which was held in Washington, December 11 and 12, 1884, a preliminary statement of the work then accomplished and contemplated was made, and in accordance with authority received from the Executive Committee of the American Public Health Association, a series of *preliminary reports* has been published during the present year, in a medical journal of wide circulation, the *Medical News*, of Philadelphia. To Messrs. Lea Bros. & Co., the publishers of the journal mentioned, the Committee is indebted for substantial aid afforded in rendering the results of the Committee's work promptly available to sanitarians and the public.

The compensation received for the papers published in the *Medical News* was kept as a separate fund to cover the cost of printing the report herewith submitted. A considerable deficiency has resulted, responsibility for which has been assumed by individual members of the Committee. GEORGE H. ROHÉ, Secretary.

FINANCIAL STATEMENT.

RECEIPTS.		EXPENDITURES.	
From American Public Health Association,	$50.00	Laboratory Expenses	$264.18
" H. Lomb, Esq ,	50 00	Salaries of Assistants,	400.00
" W. G. Little, Esq.,	50.00	Printing, Binding and Mailing Preliminary Report, Stationery, Postage, Express Charges and Incidental Expenses,	82.97
" Connecticut State Board of Health,	50 00		
" Illinois " "	50.00		
" Iowa " "	50.00		
" Louisiana " "	25 00		
" Massachusetts " "	50.00		
" Michigan " "	50.00		
" New York " "	50.00		
" South Carolina " "	25 00		
" Wisconsin " "	25.00		
" Provincial Board of Health, Canada,	25.00		
" Boston " "	25 00		
" Brooklyn " "	100.00		
" Charleston " "	25.00		
" Pittsburg " "	25.00		
" Sanitary Protection Association, Newport, R. I.,	10.00		
" Members of the Committee,	12 15		
Total	$747 15	Total	$747.15

PRELIMINARY REMARKS BY THE CHAIRMAN OF THE COMMITTEE.

A complete investigation of both disinfectants and antiseptics being impracticable in the time and with the resources at command the Committee decided upon so far departing from the letter of the resolution under which it was appointed as to limit its investigations to the subject of disinfectants, properly so-called—that is, to *those agents which are capable of destroying the infecting power of infectious material.*

In the experimental investigations made by the writer in the biological laboratory of Johns Hopkins University, the biological test of disinfecting power has been the only one employed. In applying this test a variety of micro-organisms have been subjected to the action of the various agents under trial, and the object in view has been to determine, within sufficiently narrow limits for practical purposes, the percentage in which these agents are capable of destroying the vitality of the test-organisms in a given time. This is determined by a series of experiments in which the agent being tested is used in a greater or less amount, according as it is found to fail or to be effective. Failure is shown by the fact that the test-organisms grow in a suitable culture medium, after having been exposed to the action of the disinfectant; on the other hand failure to multiply in such a solution is evidence that the test-organisms have been killed. Further details with reference to the method will be found in the paper on *Commercial Disinfectants,* and also in my paper published in the *American Journal of Medical Sciences,* April, 1883, in which I give the results of an extended series of experiments of a similar nature.

Experiments of this kind require a certain amount of

technical skill and a very great expenditure of time. Results which are recorded in a single paragraph have often been reached only after making numerous experiments extending through days or even weeks.

It would of course be desirable to test each disinfecting agent upon a variety of pathogenic organisms, and there is no doubt that, within certain limits, differences in resisting power would be found. But this would be a task involving a still greater expenditure of time and money, and one which should follow the more general study which we have made.

The work already done is sufficient to justify the general statement that, *in the absence of spores, an agent which destroys the vitality of one micro-organism of the class to which known disease germs belong will destroy all other organisms of the same class*, although not necessarily in the same amount, or in the same time.

The fact that a certain agent destroys micrococci and bacilli without spores can not, however, be taken as evidence that the same agent will destroy spores, for these reproductive bodies have a far greater resisting power, and certain chemical agents—e. g., carbolic acid, sulphur dioxide—which are germicides, in comparatively small amounts, so far as micro-organisms in active growth are concerned, are quite impotent for the destruction of spores.

It has not been possible to make an exhaustive study of disinfectants, and the agents selected for experimental work have been chosen from a practical point of view, the object having been to fix as nearly as possible the value of those agents most relied upon by sanitarians for disinfecting purposes, and the conditions of successful disinfection with them.

George M. Sternberg, Chairman.

EXPERIMENTAL DATA.

COMMERCIAL DISINFECTANTS. No. 1.

By George M. Sternberg.

In conducting the experimental investigations of the Committee on Disinfectants, the writer determined at the outset, in the interest of health officials and of the public, to ascertain the comparative value of the various commercial disinfectants in the market. In a recent paper by Wynter Blyth, Medical Officer of Health for Marylebone, in which the commercial disinfectants, exhibited at the London Health Exhibition, are intelligently discussed, we find the following:

"Rampant rides the quack in the fields, both of preventive and remedial art. Quackery takes a well-known common powder, labels it with a grand mystic name, selling bright copper at the price of gold. Quackery finds a stink outstinking feebler stinks, and gives it forth as a disinfectant. Of all the substances gathered together under the name of disinfectants—solids, vapors, gases and odors—a small percentage alone possess any value."*

This statement applies as well to many of the articles advertised as "disinfectants" in this country. But in justice to the manufacturers of these so-called disinfectants, we must say that many of them which are of no use in the sense in which we use the term are valuable as antiseptics, or as deodorizers, and that there is good authority for calling a substance which will prevent putrefactive decomposition, or which will destroy bad odors, a disinfectant. Many chemists and physicians use the word in this sense, and this is the popular acceptation of the term both in this country and in Europe. We, therefore, cannot find fault with those manufacturers

* Med. Times and Gaz., London, Oct. 11, 1884.

who see fit to use the word as synonymous with deodorizer or antiseptic, but we must caution the public that a disinfectant from this point of view does not necessarily destroy infectious material; and that the word is used by this Committee in accordance with the definition given in the introduction to this report.

It has been proved that certain kinds of infectious material owe their infecting power to living micro-organisms, which in a general way are often spoken of as "germs." A disinfectant, therefore, which destroys this kind of infectious material may be called a *germicide*. If all infectious material owes its specific infecting power to the presence of living organisms, then, from our point of view, disinfectant and germicide are synonymous terms. But in the absence of satisfactory proof that such is the fact, we must consider the former term one of general application, while the latter is only applicable in those cases in which the infecting agent has been proved to be a germ. But in our tests of disinfectants we are obliged, for the most part, to depend upon experiments which determine germicide power, and in the experiments reported below, only biological tests have been used. As a matter of fact, those agents which by laboratory experiments have been proved to be the most potent germicides, have by the experience of sanitarians, by tests upon vaccine virus, septicæmic blood, etc., been shown to be the most reliable disinfectants.

Evidently there can be no partial disinfection; either the infecting power of the material to be disinfected is destroyed, or it is not. Where the object is to destroy disease germs in the sputum of patients with diphtheria, in the discharges of patients with typhoid fever, etc., so that no development shall occur when these germs find a proper nidus, incomplete destruction will be a waste of ammunition, for so rapid is the multiplication of these low organisms that the question of numbers is of secondary importance. It is therefore essential, in an experimental inquiry of this kind, that the most rigid tests may be applied, and that we keep on the safe side in the practi-

cal application of those agents which withstand these tests.

In our experiments below reported, the material which has served to test the germicide power of the agents named is "broken-down" beef-tea, exposed in the laboratory for several days, and containing a variety of putrefactive bacteria and their spores. The spores of *Bacillus subtilis* are also invariably present in this stock, and when a certain agent is successful in destroying all other microorganisms, we frequently have in our culture-solutions a pure culture of this bacillus, which is noted for its abundant and wide distribution, and for the great resisting power of its spores. In order to meet the objection of those who are likely to cavil because no "disease germs" are present in the material mentioned, a culture of *Bacillus anthracis* containing spores is added to this stock solution. It is well known that anthrax spores constitute one of the most difficult tests of germicide power; not more difficult, however, than the spores of *B. subtilis*. We may safely assume, then, that an agent which will destroy these spores will also destroy all known disease germs, and probably all organisms of this class, known or unknown. The micrococci and bacilli not containing spores are far more easily destroyed.

The time of exposure to the disinfecting agent in all of these experiments has been two hours. And the amount of material to be disinfected has in every case been made equal to the amount of the solution of the disinfecting agent under trial. Thus to test an agent in the proportion of fifty per cent., a certain quantity—10 cc.—of the agent undiluted (100 per cent.) is added to an equal quantity of the broken-down beef stock described. If we wish to test the agent in the proportion of four per cent., an eight per cent. solution is made, and this is added to an equal quantity of the stock, etc. The mixture is placed in a wide-mouthed bottle containing 25 cc. and is set aside for two hours. A minute quantity of the material is then introduced into two little culture-flasks* (all ex-

*The flasks used are all made in the laboratory, and are of the form described in the chapter on Technology in my book—*Bacteria*.

periments are made in duplicate) containing sterilized beef-tea, and these are placed in the oven, which is kept constantly at a temperature of 36° to 38° C. (96.8° to 100.4° F.) My method has been explained in detail in a paper relating to an extended series of experiments of a similar nature, published in the *American Journal of the Medical Sciences* for April, 1883.

These experiments on commercial disinfectants have been very carefully made, under my direction, by Dr. Duggan. The samples were, for the most part, obtained for me by Dr. Raymond, Health Commissioner of Brooklyn, and a member of the Committee, in the cities of New York and Brooklyn. As the experiments are made in the interests of the public, special pains have been taken to secure samples such as are placed in the market, and the rule was adopted at the outset not to test samples sent to us by the manufacturers, but to purchase ourselves such packages as are offered for sale by druggists and other dealers.

Numerous experiments were made, but only those are recorded here which fix the limits between success and failure. In four instances, a failure occurred in the proportion of 50 per cent., *i. e.*, when the undiluted solution was added to an equal quantity of the test-material. These agents were at once dropped without further trial. In the table, the agents are arranged with reference to their relative efficiency.

List of Commercial Disinfectants Tested.

Name upon Label.	Per cent. in which active.	Per cent. in which failed.
Little's Soluble Phenyle (Morris, Little & Co., Brooklyn),	2	1
Labarraque's Solution (*Liq. Sodæ Chlorinatæ*); name of manufacturer not given	7	5
Liquor Zinci Chloridi (Squibb's),	10	7
Feuchtwanger's Disinfectant (L. Feuchtwanger & Co., New York),	10	8
Labarraque's Solution (from Freré, Paris),	15	10

Phenol Sodique (Hance Bros. & White, Philadelphia),	15	10
Platt's Chlorides (Henry B. Platt, New York),	20	15
Girondin Disinfectant (James Meyer, Jr., New York),	25	15
Williamson's Sanitary Fluid (D. D. Williamson, New York),	25	20
Bromo-chloralum (Bromo-chemical Co., New York),	25	20
Blackman Disinfectant (Blackman Disinfectant Co., New York),	30	20
Squibb's Solution of Impure Carbolic Acid (about two per cent.),		50
Burchardt's Disinfectant (J. H. Harty & Co., New York),		50
Phenol Sodique (7 Rue Coq. Héron, Paris),		50
Listerine (Lambert & Co., St. Louis),		50

I append to this list the report made by Wynter Blyth (loc. cit.) upon certain commercial disinfectants exhibited at the London Health Exhibition:

"*Various tar-acid disinfectants.*—Jeyes' perfect purifier, the concentrated carbolated creasote of Messrs. D. & W. Gibb, the kresylene described by Messrs. Mackay & Co. as a preparation of coal-tar creasote, pixene, and the thymo-cresol exhibited by Messrs. Ness & Co., have all the property of emulsifying with water. Jeyes' purifier was for some time tried in St. Marylebone urinals and drains, but the deposit left on the surface with which it had been in contact was found difficult to cleanse and inconvenient. I have made some experiments on anthrax in the spore state with the 'perfect purifier.' The solutions used were five to ten per cent.; the 'fluff' had to be freed from the tenacious fawn-colored deposit by alcohol. The result was very similar to what might have been predicted from results of experiments on the pure tar-acids, viz., growth was a little delayed, but never destroyed."

"Mr. James Wheeler's pixene I was on the whole favorably impressed with. He claims to have condensed the whole of the volatile constituents of pure tar, and to have presented them in a form readily miscible with water. . . . . Anthrax spores soaked in a ten per cent. solution did not grow for some time."

"*Carbolic acid powders.*—I have experimented on anthrax with Calvert's, Jeyes' and McDougall's powders; but

even when a paste was made with the several powders, and the infected 'fluff' allowed to remain therein twenty-four hours, no sterilization resulted."

Similar powders were obtained by our Committee in New York and Brooklyn, but I have not thought it worth while to make any experiments with them, as sawdust, or other material, saturated with impure carbolic acid, or with the volatile constituents of tar, can have no great value, in view of the low disinfecting power of these agents minus the sawdust. An agent which has gained considerable reputation in England is referred to as follows by Blyth:

"*Sanitas.*—Of all the substances introduced under the name of disinfectant, this is the most pleasant. Sanitas is chiefly in the form of sanitas oil and sanitas fluid; peroxide of hydrogen, thymol, camphoric acid, and terebene enter into their composition. Of the numerous sanitas preparations, liquid and solid, the oil seems to be the most active. Nothing replaces or destroys so rapidly the unpleasant odor which tenaciously adheres to hands contaminated by offensive animal matters. It is also to be commended for use in stables, and as a corrective for dung-heaps, and of the sickly smell at times rising from the Metropolitan wood pavement. I made many experiments with sanitas on anthrax. Spores soaked in sanitas fluid for twenty-four hours grew afterwards very freely. Spores placed in the undiluted emulsion, and afterwards removed, seemed at first to have their growth delayed, but in forty-eight hours growth commenced, and ultimately became luxuriant. The oil itself gave similar results. Sanitas powder was also tried, but with no better success."

Returning to the disinfectants in our list, it will be seen that all but the four last named are efficient in various amounts, ranging from 30 to 2 per cent. But the relative value of the agents as here given does not establish their comparative practical value as disinfectants. Questions of cost, physical and chemical properties, etc., come into the account which it is the province of other members of our Committee to consider.

We have nothing to say against the use of any of the agents in our lists as antiseptics or as deodorizers. No

doubt all of them are more or less useful for this purpose, and we have no desire to restrict their use. But the exaggerated claims made in relation to the germicide, or disinfectant power of certain of these agents, may do immense harm. Thus, one agent advertised as a "germicide" *par excellence*, "Pasteur's marvelous disinfectant," failed *after two hours' exposure* to kill the organisms in our test solution in the proportion of twenty per cent. Yet this fluid is, by some contrivance, to be thrown into the water-closet of every germ fearing citizen when he pulls the handle, so that it may catch the germs on the fly and extinguish their power for mischief before they reach the sewers. On the whole, the proprietary disinfectants have turned out better than I anticipated, and any one of the eleven first named may be used in conformity with the conditions imposed by the experimental test for disinfecting sputum or excreta. For fecal matter however, it will be best to employ an agent which is successful in the proportion of ten per cent., for example, in at least twice this strength, and in quantity considerably in excess of the material to be disinfected. It must be remembered that in our experiments the germs are suspended in a fluid and this is thoroughly mixed with the disinfectant.

The second agent in our list is the well-known *liquor sodæ chlorinatæ*.

Our experiments lead me to think that this time-honored disinfectant is worthy of more attention than it receives to-day, when so many other agents of inferior value are being pushed by enterprising manufacturers. Our two samples differ greatly in their disinfecting power, which depends upon the amount of sodium hypochlorite present. Dr. Duggan has prepared, and experimented with, a solution containing six per cent. of available chlorine, which proves to be efficient in the proportion of one per cent. I am informed that a solution containing two per cent. of available chlorine could be put in the market for less than forty cents per gallon. Whether this is to be the disinfectant with which we shall fight cholera, must be

determined by my colleagues who take up the question from a practical standpoint. But whatever agents are determined to be the best, must be so cheap that they may be obtained by the gallon and used without stint. The time has passed when *pater familias* can complacently congratulate himself upon having disinfected his house with a bottle of carbolic acid which he has brought in his vest-pocket from the corner drug-store.

In view of the efficiency and cheapness of the hypochlorites, I have requested Dr. Duggan to give special attention to these agents, and to prepare a report embodying the results of his biological tests, and such information relating to the *modus operandi*, chemical characters, and available tests of strength, as may be useful to health officers and to the public.

GERMICIDE POWER OF THE HYPOCHLORITES.

By J. R. Duggan, M.D., Ph.D.,

In my previous work on commercial disinfectants, I found that the specimens of Labarraque's solution of sodium hypochlorite, although containing only a small quantity of this salt, were among the most effective in their action. On looking over the literature of the subject, I found that although this solution and that of the corresponding calcium salt (chloride of lime) were among the first used disinfectants, very little had been done to fix accurately their value. In order to determine this, I prepared standard solutions of sodium and calcium hypochlorites for use in the following experiments. The available chlorine, that is, the chlorine which enters into the constitution of the hypochlorites, was determined in these solutions by its oxidizing action on a standard solution of arsenious acid ; papers saturated with starch paste and potassium iodide being used to show an excess of the hypochlorite. The well-known method of Dr. Sternberg was used throughout the investigation to determine germicidal value. The following solutions were prepared :

Solution A: Sodium hypochlorite made by passing chlorine gas into a solution of sodium hydroxide. Available chlorine = 6 per cent.

Solution B: Calcium hypochlorite made by passing chlorine gas into milk of lime. Available chlorine = 6 per cent.

Solution C: Calcium hypochlorite made by dissolving 100 grammes of bleaching powder (chloride of lime) in 1 litre of water, and filtering. Available chlorine = 2.4 per cent.

Solution D: Potassium hypochlorite made by passing chlorine gas into a solution of potassium hydroxide, and diluting until the available chlorine = 1 per cent.

The action of Solution A on spores of *Bacillus anthracis* was tried with the following result: 2 per cent was effective in 30 minutes, 1 hour, and 2 hours; 1 per cent. failed in 1 hour, effective in 2 hours.

Solution B in 2 per cent. gave similar results. In 1 per cent. it was effective in both 1 and 2 hours.

Solutions A and B were both found to be effective in 5 per cent. and 1 minute's time on the organisms of broken down beef-tea. One-half per cent. of these solutions failed to destroy in 2 hours organisms in broken-down beef-tea, but 1 per cent. of Solution A was effective in the same time. One of the bulbs from a 1 per cent. solution of Solution B broke down, but the other remained clear. These solutions were also tried in 2 and 3 per cent. for two hours and found effective.

Solution C was effective in 3 per cent., but failed in 1 and 2 per cent. in 2 hours.

Solution D was effective in 7 per cent., but failed in 5 and 6 per cent. in 2 hours.

In addition to these, we may mention a dilute solution of bleaching powder of unknown manufacture. This contained .4 per cent. available chlorine, and was effective in 15 per cent., failed in 10 per cent.; time, 2 hours. The commercial specimens of Labarraque's solution, reported among the commercial disinfectants, showed about the same value in proportion to the available chlorine they

contained. These latter experiments were all made on broken-down beef-tea. That this contained spores as well as organisms, was shown by the fact that tubes inoculated from the solution while boiling developed various bacilli. Of course spores must have been present to resist this temperature.

While it has been thought well to use a pathogenic organism in some of these experiments, I am convinced, from recent work on the subject, that any agent that will destroy *Bacillus subtilis* will also destroy *B. anthracis* and probably any other pathogenic organism.

The foregoing experiments show that a solution containing .25 of 1 per cent. (1 part to 400) of chlorine as hypochlorite is an effective germicide even when allowed to act for only 1 or two minutes, while .06 of 1 per cent. (6 parts to 10,000) will kill spores of *B. anthracis* and *B. subtilis* in 2 hours. A simple calculation will show that all the solutions used were effective when diluted to about this strength, and failed a little below it. No better evidence could be had of the reliability of the excellent method of Dr. Sternberg for testing agents of this kind. These experiments were all made in duplicate, and they show a concordance which I am satisfied can be obtained by no other method with which I am acquainted.

The value of the various commercial preparations, such as Labarraque's solution and bleaching powder (chloride of lime), of course depends on the amount of available chlorine they contain, since the chlorides and chlorates are of very little value as disinfectants. Bleaching powder usually contains from twenty-five to forty per cent. of available chlorine. For most purposes a solution containing 1 part of this preparation to 100 of water is strong enough for this will contain from .25 to .40 of one per cent. of chlorine as hypochlorite. As is stated above, the smaller of these quantities is sufficient to destroy spores almost instantly. There are very few purposes to which disinfectants are applied that are not fulfilled by this solution of 1 to 100 of bleaching powder. It is not poisonous, does not injure clothing, bedding, etc., and is almost with-

out cost, since bleaching powder is worth only about five cents per pound. The sodium salt furnishes in some respects a more elegant preparation, since it leaves on evaporation sodium chloride instead of the hygroscopic calcium chloride. If prepared according to the U. S. P. it does not keep very well, but when made by passing chlorine gas into a solution of an excess of caustic soda, it shows very little tendency to undergo decomposition. Solution A, although rather concentrated, and frequently exposed to the light and air, has kept for a month without any appreciable change. A solution like this might be put on the market at a very reasonable price, and as it should be diluted with twenty parts of water, it would be far cheaper and more effective than any of the proprietary disinfectants. The odor of the hypochlorites is a slight objection to their use, but in dilute solution this is scarcely disagreeable. Where the odor is not to be regarded, the hypochlorous acid may be liberated by the addition of any common acid, thus increasing the oxidizing power, and liberating a most effective gaseous disinfectant. I hope to make further experiments on this point at an early day.

To fix the value of solutions of the hypochlorites, the following method is sufficiently accurate for ordinary purposes. A standard solution of potassium arsenite may be made by diluting seven parts of Fowler's solution with one and a half parts of water. This corresponds to to a one-half per cent. solution of available chlorine. To apply the method, a given volume of the hypochlorite solution is measured out, and the arsenite solution added in small quantities. Between each addition the mixture is well stirred, and a drop taken out on a glass rod and tested on a strip of paper saturated with iodide of potassium and starch paste and dried. As long as any hypochlorite is present, the blue iodide of starch is formed; but when it has all been used up in converting the arsenite into an arseniate, the paper will remain colorless. As each volume of the potassium arsenite solution required for this corresponds to one-half per cent. of available chlorine, the

calculation is very simple, *e. g.*, if one volume of the hypochlorite solution = 4.6 volumes of the arsenite solution the amount of available chlorine present would correspond to 2.3 per cent. Since the preparations now on the market vary so much in the amount of chlorine they contain, this test should always be used to determine their value, and the amount of dilution required. Where the disinfectant is further diluted in use by being added to liquids or semi-solids, the original dilution should not be so great.

The hypochlorites possess the advantage over many of the metallic salts of not forming a coating of insoluble albuminoid matter around the solid or semi-solid masses, and thus protecting them from further action. On the contrary, when used in moderately strong solution, they oxidize and disintegrate these materials. They are at the same time destroyed themselves in the reaction, so that we are rid of germs, organic matter, and disinfectant all at the same time.

NOTE.—The fact that the oxidizing disinfectants are destroyed in the reaction to which their disinfecting power is due, makes it necessary to use them in excess of the amount of organic material to be destroyed, otherwise germs included in masses of material not acted upon would be left intact in a fluid which is no longer of any value for their destruction, and as a few germs may be as potent for mischief as a large number, there would be a complete failure to accomplish the object in view. For this reason the metallic salts, such as mercuric chloride, which are not destroyed by contact with organic material, have a superior value for the disinfection of masses of material left *in situ*, such as the contents of privy vaults and cess-pools. In this case, even if germs enclosed in an envelope of the albuminate of mercury escape destruction, they will be prevented from doing mischief so long as they are included in such an envelope, and the wonderful antiseptic power of the agent used will prevent any development, probably for a sufficient length of time to ensure the complete loss of vitality of any pathogenic organisms present.

GEO. M. STERNBERG.

COMMERCIAL DISINFECTANTS. No. 2.

By George M. Sternberg.

The following named "disinfectants" have been tested, under my direction, by my efficient laboratory assistant Dr. A. C. Abbott, of Baltimore. The test in every case has been made upon "broken-down" beef tea by the method heretofore described in detail.

Several of the disinfectants which stand at the head of the list contain the potent germicide mercuric chloride, as shown by the simple test of introducing a polished piece of copper into the solution. A deposit of metallic mercury upon the surface of the copper shows at once the presence of a soluble salt of this metal. Those who have occasion to use disinfectants, the exact composition of which is not made public, will do well to bear this in mind, and to remember also that the germicide power of such solutions is neutralized by contact with lead, copper or tin, and that lead pipes are injured by passing through them solutions of corrosive sublimate in any considerable quantity.

	Per cent. in which active.	Per cent. in which failed.
Dr. Martin's "Disinfectant No. 1" (contains mercuric chloride) . . .	2	1
"Thymo-cresol," English preparation, name of proprietor not given . .	2	1
"Withers' Antizymotic Solution" (contains mercuric chloride)	4	2
"Pasteur's Marvellous Disinfectant,"* Blackman Disinfectant Co., of New York (contains mercuric chloride)	4	2
"Purity," Egyptian Chemical Co., Boston	40	20
"King Disinfectant," Humiston Manufacturing Co., New Haven, Conn.,		50
"Sanguantræ," P. W. Manning, Stoneham, Mass.		50
"Phenoline," Hance Bros., & White, Philadelphia		50

* A preparation bearing the same name, reported upon in previous report upon commercial disinfectants, did not contain mercuric chloride and failed at 20 per cent.

"Golden Purifier," Thomas & Thompson, Baltimore	50
"Smith's Odorless Disinfectant," The Louis Smith Co., N. Y	50
"Disinfecting Powder," G. L. Kidwell, Georgetown, D. C.	50
"Thymo-cresol Powder," English preparation, name of proprietor not given	50
"Chloridium," Chemical Vaporizer and Deodorizer Co., of N. Y. . .	50
"Carbolcrystal Disinfectant," H. H. Childs, proprietor	50

Dr. Abbott has also tested for me the different preparations of chloride of lime, and of Labarraque's solution which we have been able to obtain in the Baltimore market, with the following result:

Chloride of Lime.	Per cent. of available chlorine.
Brookman Manufacturing Co., Chicago . .	33.50
Risley & Co., New York	28.40
Rock Hill Alkali Co., Liverpool	28.00
Clagett Bros.	24.10

Labarraque's Solution (*liquor sodæ chlorinatæ*).

Reed & Carnrick, New York	3.80
Parke, Davis & Co., Detroit, Mich.	2.75
Powers & Weightman, Philadelphia . . .	2.62
Hance Bros., & White, Philadelphia . . .	0.35
Alonzo L. Thompson, Baltimore	0.013

NOTES.*

By the Chairman of the Committee.

My attention has just been called to an advertisement of "Withers' Antizymotic Solution," in which it is stated that it is endorsed as the best by George M. Sternberg, M.D., Surgeon U. S. A.

I have never authorized the use of my name in connection with this or any other proprietary disinfectant. The only reference I have ever made to "Withers' Antizymotic Solution" is in the report on "Commercial Disinfectants," No. 2,† published in the *Medical News* of June 13th, where this has the *third* place in a list of fourteen commercial disinfectants, tested under my direction by Dr. Abbott. The remark is made, "contains mercuric chloride." As a simple solution of mercuric chloride of 1: 500 would be quite as efficient as a 4 per cent. solution of this disinfectant, the extravagant claims made for it are without foundation. The assertion, that it is endorsed by me "as the best," is untrue.

Labarraque's Solution.—I have received the following letter from a well-known and reputable firm of manufacturing chemists :

"In the *Medical News* (Philadelphia), for June 13th, we find a continuation of the Preliminary Report of the Committee on Disinfectants, including a report on the relative percentage of available chlorine in samples of different manufacturers of Labarraque's Solution. As you are doubtless aware, Labarraque's Solution is a very unstable preparation ; and, although made with every possible care, will surely deteriorate by age. With such an article it is manifestly unfair to institute comparisons between different makers without regard to the freshness or otherwise, of the samples. To the unthinking reader, the bald statement that one preparation contains 3.8 per cent., and another only 0.013, is calculated to convey the impression that the preparation which contained so small a percentage has been improperly made (while really

* Medical News. September 5, 1885.

† See ante, p. 15.

when fresh its percentage might have been greater than the highest named); and such an impression would naturally create a prejudice against the manufacturer, and, unfortunately, not be limited to the particular article mentioned."

I recognize the fact that the unthinking reader might make an inference unfair to the manufacturer from the perusal of a "bald statement," such as is published in the table on page 659 of the *News*. I regret this, and will in future gladly give the date of manufacture, if the manufacturers will stamp it upon the bottle. As I propose to obtain new samples from time to time, and to publish the results of tests as to available chlorine, it may happen that the aggrieved manufacturers in this instance will come out at the head of the list next time. But these tests are made especially in the interests of the public, which, from my point of view, are superior to those of the manufacturers, and it is evident that great harm might result from reliance upon the disinfecting power of a liquid labelled "Labarraque's Solution," which contained only 0.013 per cent. of available chlorine. The fact that it was of full strength when first manufactured, does not add to its value as a disinfectant for the excreta of a patient with cholera or typhoid fever. If the manufacturers will stamp the date of manufacture upon the label attached to each bottle, I will publish it, in future, in connection with the result of the tests to determine available chlorine present in the solution.

POTASSIUM PERMANGANATE.

By Geore M. Sternberg.

In my experiments made in Baltimore in 1881 * it was found that a two per cent. solution of potassium permanganate was required to destroy the virulence of septicæmic blood, the test of disinfection being inoculation into

* Bulletin National Board of Health, July 23, 1881; also, Studies from Biological Labratory of Johns Hopkins University. Vol. ii, No. 2.

healthy rabbits. In experiments made in San Francisco, in 1883* it was found that 0.12 per cent (= 1:833) destroyed the micrococcus of pus in culture solutions. As the virulence of the blood in the first experiments was demonstrated to be due to the presence of a micrococcus which has, as a rule, less resisting power for chemical agents than has the micrococcus used in the second series of experiments, it may be thought that these results are contradictory. This is not, however, the case, and the wide difference as to the quantity of the disinfecting agent required in the two series of experiments depends upon an essential difference in the nature of the fluid in which the germs to be destroyed were contained. The large amount of organic material present in the blood as compared with that in the culture fluid used in the second series of experiments fully accounts for the difference, for the disinfecting agent is itself quickly destroyed by contact with organic matter, and, indeed its disinfecting power depends upon this instability of composition and upon the oxidation of organic material with which it comes in contact.

This difference in the result due to a difference in the amount of organic matter present in the material to be disinfected is further exemplified in the following experiments :

November 26, 1884, a single drop of a pure culture of micrococcus of pus was subjected to the action of potassium permanganate for two hours, in the proportion of 1 part to 500, and in the proportion of 1 part to 1000. Four culture-tubes containing a sterilized solution of beef-peptone were inoculated with the micrococci thus exposed (it is my practice to make every experiment in duplicate), and were placed in a culture-oven maintained at 38° C. (100.4° F.) for forty-eight hours. No development occurred in either of the tubes.

On the 29th of November, a similar experiment was made with a culture solution containing both micrococci and bacilli. In this experiment there was no develop-

* Am. Journ. of the Medical Sciences, April, 1883.

ment of the micrococci. but the bacilli developed abundantly after exposure to the 1:1000 solution. No development of bacilli (*B. Subtilis*) occurred, however, after exposure to 1 part in 250. In these experiments the permanganate, although in dilute solution, was not neutralized by the small amount of organic material contained in the drop of the culture fluid exposed to the action of the germicide agent. In the following experiments the conditions were varied, and a larger proportion of the permanganate failed to exert any germicide power.

November 24, equal parts of a 0.4 per cent solution (1:250) of potassium permanganate and of "broken-down" beef-tea were mixed in a germ-proof receptacle, and allowed to stand for two hours. Two culture-tubes were then inoculated with a minute drop of the mixture, and were placed in the oven. At the end of twenty-four hours, an abundant development of putrefactive bacteria had taken place. In this experiment, then, we have a failure in the proportion of 1:500, but the experiment does not in the least invalidate those previously reported. The truth is, that in making the above mixture the permanganate is almost instantly decomposed by the excess of organic matter, while in the experiments in which a single drop of culture-fluid containing micrococci was introduced into a more dilute solution, there was still an excess of the permanganate, as shown by the color of the solution at the end of two hours. Having determined the germicide power of the permanganate for micrococci, at least for one species of *Micrococcus*, I desired to know whether the oxidizing power of this reagent, when present in excess, would destroy the spores of anthrax, which are recognized as furnishing one of the most difficult tests of germicide power. The following experiments have been recently made :

November 24th, a drop of culture fluid, containing an abundance of anthrax spores, a pure culture, was added to a considerable quantity of a 0.4 per cent. (1 :250) solution of potassium permanganate. After two hours, two culture-tubes were inoculated with a minute quantity of

this material. These tubes were placed in the culture-oven, and the following morning contained an abundance of anthrax bacilli.

November 27th, the above experiment was repeated, except that the time of exposure was extended to four hours. Again there was an abundant development of anthrax bacilli in the culture-tubes, showing that the spores had resisted; but in one tube the development was delayed, and it was only on the morning of the second day that flocculi of *bacillus anthracis* commenced to appear.

December 2d, the experiment was repeated, with the exception that the time of exposure was extended to four days. The bacillus now failed entirely to develop in the culture-tubes, showing that the spores had been killed by this long exposure.

It is probable that in experiments in which the permanganate is present in excess, the amount present is of less importance than the time of exposure, and that a stronger solution would fail to destroy anthrax spores in a considerably shorter time. The resisting power of anthrax spores to this reagent is shown by these experiments to be greater than that of the spores of *B. subtilis*. This is true, also, of chloride of zinc, and no doubt of certain other chemical agents. On the other hand the spores of *B. subtilis* have a greater resisting power for heat. These differences in resisting power show that it will be necessary to exercise due caution in applying the data obtained in experiments upon one pathogenic organism in our practical efforts to disinfect material containing a different organism.

According to Arloing, Cornevin, and Thomas, a five per cent. solution destroys the fresh virus of symptomatic anthrax, but has no effect upon the dried virus.

One per cent. was found by Koch not to destroy the spores of anthrax, but in the proportion of 1:3000 the development of these spores was retarded.

The experiments of De la Croix, like those of Miquel, have reference especially to the antiseptic power of the

agents tested by him. He makes the statement, however, that one part of potassium permanganate in thirty-five, kills the bacteria of broken-down beef-tea. This statement is, no doubt, true, under the conditions of his experiment; but, as I have shown, the result depends upon the time of exposure and the amount of organic matter present, quite as much as upon the proportionate amount of permanganate with reference to the quantity of fluid operated upon. If we add one gramme of permanganate to a litre of broken-down beef-stock, it is quickly decomposed, and no germicide effect is produced; but if we add one drop of putrid beef-tea to a litre of distilled water containing one gramme of permanganate, the organic matter, and the germs as well, contained in this drop of fluid are quickly destroyed by oxidation.

Several English investigators—Notter,* Calvert,† and Tripe‡—have attempted to determine the value of potassium permanganate as a "disinfectant;" but the methods employed have not been such as could give satisfactory and definite results, although these earlier experiments demonstrated the value of this agent as an antiseptic and deodorizer.

Other English investigators—Baxter,§ Braidwood and Vacher‖—have adopted a different test, and their results are interesting and valuable.

These gentlemen operated upon vaccine lymph, and the test of disinfection was the failure of this lymph to produce characteristic vesicles upon the arms of children not previously vaccinated. Comparative experiments were made in each case with lymph not subjected to the action of the disinfectant.

In Baxter's experiments, one part in 200 was successful in destroying the specific virulence of vaccine lymph; and in those of Braidwood and Vacher, a like result was

* Dr. J. Lane Notter, Dublin Journal of Medical Sciences, vol. lxviii. (1879), p. 196.

† Dr. Grace Calvert, Chemical News, London, vol. xxii. (1870), p. 281.

‡ Dr. John W. Tripe, Sanitary Record, London, vol. ii, (1881) p. 201.

§ Dr. E. B. Baxter, Report on the Experimental Study of Certain Disinfectants. Report Medical Officer Privy Council, etc., N. S. No. vi. (1875) p. 216.

‖ British Medical Journal, London, vol. ii. (1876).

obtained by adding two drops of a solution of 1:120 to "a tube of lymph."

From what has been said, it is evident that, while potassium permanganate has decided germicide and antiseptic power, it is not generally applicable for purposes of disinfection, because of the readiness with which it is decomposed by organic matter. It is, however, a prompt and valuable deodorizer.

HYDROGEN PEROXIDE.

By George M. Sternberg.

Since Angus Smith, in 1869, proclaimed his belief that peroxide of hydrogen was to be the disinfectant of the future, sanitarians have been waiting for chemists to devise some method by which this agent may be manufactured at a sufficiently low price to bring it into general use. The absence of any corrosive or poisonous properties or of any objectionable odor, and the promptness with which this agent destroys volatile putrefactive products and arrests putrefactive decomposition, seemed to make it the disinfectant *par excellence*. But we no longer accept the arrest of putrefactive decomposition or the destruction of bad odors as evidence of disinfecting power, and the question which here concerns us relates to the power of this agent to destroy germs.

The following experiments have been made by Dr. Duggan and myself with a solution of hydrogen peroxide prepared under the direction of Prof. Albert R. Leeds, a member of the Committee on Disinfectants. When first received from Dr. Leeds, this solution contained 4.8 per cent. of H_2O_2 and 5 per cent. of sulphuric acid. At the expiration of a month the amount of hydrogen peroxide was again estimated by Dr. Duggan, and was found to be 3.98 per cent. Five weeks later the proportion was reduced to 2.4 per cent. The constant escape of oxygen at the temperature of the laboratory is shown by

a continuous flow of minute bubbles from the interior of the liquid to its surface. Tested upon broken-down beef-tea, when the proportion of H_2O_2 was 3.98 per cent. (say 4 per cent.), the solution was found to be active in the proportion of 30 per cent., while it failed in the proportion of 20 per cent.; that is to say, 1.2 per cent. of H_2O_2 in two hours' time destroyed all of the organisms present in the broken-down beef stock, and 0.8 per cent. failed to do so. Tested upon a pure culture of *B. anthracis* containing spores, the same solution was effective in 20 per cent. (0.8 per cent. $H_2O_2 = 1:125$), and failed in 10 per cent. Tested upon a pure culture of a micrococcus, obtained from a drop of blood drawn from the inflamed area in a case of vaccinal erysipelas, the same solution was effective in the proportion of 10 per cent. (0.4 per cent. of $H_2O_2 = 1:250$), and failed at 5 per cent. In experiments made at a later date (March 28th) when the strength of the solution was reduced to 2.4 per cent., *Micrococcus tetragenus* was destroyed by 10 per cent. (0.24 per cent. $H_2O_2 = 1:400$), while the same amount failed to destroy the vitality of the micrococcus of pus—pure culture obtained from an acute abscess—showing a difference in the resisting power of these two organisms.

As the solution used in these experiments contained five per cent. of sulphuric acid, which in a previous series of experiments* has been shown by the writer to be fatal to the micrcoccus of pus in the proportion of 1:200, it is evident that a failure to destroy the vitality of the same micrococcus in 1:400 does not give this solution any very notable advantage over a simple aqueous solution of sulphuric acid. The germicide power of the solution used, as tested by its action upon spores, is, however, considerably above that of sulphuric acid alone. Dr. Duggan has ascertained that to destroy all of the organisms in broken-down beef-tea requires 8 per cent. of H_2SO_4, whereas 30 per cent. of our solution of H_2O_2, containing 5 per cent. of sulphuric acid (= 1.5 per cent. of H_2SO_4), is effective.

These experiments indicate that unless chemists can

* American Journal of the Medical Sciences, April, 1883.

furnish us solutions which are more concentrated and which will keep better, we are not likely to derive any great practical benefit from the use of hydrogen peroxide as a disinfectant.

As an antiseptic our solution was found, by Dr. Duggan, to be effective in the proportion of 1:5000 (of H_2O_2, not of the dilute solution), and to fail in the proportion of 1:10,000. This does not correspond with the results reported by Miquel, who places hydrogen peroxide—*eau oxygenee*—above mercuric chloride as an antiseptic. In his table of the minimum amount of different antiseptic agents which will prevent the putrefaction of one litre of neutralized beef-tea the quantity of H_2O_2 required is stated to be 0.05 gramme (1:20,000) while the amount of mercuric chloride required to accomplish the same results is given as 0.07 gramme (= 1:14,285.)

CHLORINE, BROMINE AND IODINE.

By George H. Rohé.

Chlorine.—The most thorough and exact research into the disinfectant powers of chlorine on record, is that made by Fischer and Proskauer, and published in the second volume of *Mittheilungen aus dem Kaiserlichen Gesundheitsamte.* The material tested consisted of the spores of bacillus anthracis, spores of the various forms of bacilli found in ordinary garden soil, micrococcus tetragenus, micrococcus prodigiosus, bacillus of septicæmia of mice, bacillus of septicæmia of rabbits, aspergillus nigrescens and aspergillus ruber, micrococcus of erysipelas, sputum of tuberculosis, bacillus anthracis, bacterium of fowl-cholera, and various other non-pathogenic micro-organisms.

The observations were made both in dry air and in air artificially moistened, and the objects to be disinfected were sometimes exposed in a dry, sometimes in a moist condition. The concentration of the gas varied from 1

part in 25,000 to 1 part in 2¼. The time of exposure in the different experiments varied from one to twenty-four hours.

Anthrax spores when thoroughly desiccated and exposed to the action of a dry chlorine atmosphere containing 44.7 parts of chlorine in 100, resisted the disinfectant action of the agent completely for one hour. After three hours' exposure, germination was still free, but somewhat retarded. After twenty-four hours' exposure, disinfection was complete, the vitality of the organism being entirely destroyed.

When the air in the experimental chamber, and the spores were moistened, one hour's exposure to an atmosphere containing four per cent. of chlorine was sufficient to produce complete disinfection. If the exposure was continued for three hours, one per cent. of chlorine was an efficient disinfectant ; and if the spores were exposed for twenty-four hours,the effective proportion of chlorine could be still further reduced, if the air and and objects to be disinfected were first rendered moist.

Bacillus anthracis itself was killed in moist air. if chlorine was present, in the proportion of one part in 2500 after twenty-four hours' exposure. Even with such a minute proportion of chlorine as one part in 25,000, the development of the organism was scanty and retarded.

Spores of the various forms of bacilli found in ordinary garden soil proved a little more resistant to the action of the chlorine. When the air in the experimental chamber was very moist, however, the presence of one per cent. of chlorine, and upward, rendered the spores incapable of development after three hours' exposure. When the chlorine strength was four per cent., one hour's exposure was sufficient to destroy the germinative power of these spores.

Micrococcus tetragenus was killed in moist air by the presence of so small a proportion of chlorine as 1 in 25,000, if the exposure was prolonged to twenty-four hours. Exposure for less than three hours was not sufcient to destroy the life of the organisms in all cases.

Micrococcus prodigiosus, and several other varieties of pigment-forming micrococci, showed themselves generally more resistant to the disinfectant than micrococcus tetragenus. In other respects, they behaved similarly, exposure for upward of three hours being sufficient to destroy them in the presence of over four per cent. of chlorine.

Aspergillus nigrescens and aspergillus ruber were rendered incapable of further growth by exposure for one hour to moist air containing one part of chlorine in 25,000.

Micrococcus of erysipelas was killed by three hours' exposure to moist air containing one part of chlorine in 2500, or twenty-four hours' exposure to air containing 1 in 25,000.

Bacillus of septicæmia of mice was killed by exposure to an atmosphere containing from 3 to 40 parts of chlorine per thousand. The presence of 5 parts per thousand was effective after one hour's exposure in a moist atmosphere.

Bacillus of septicæmia of rabbits was killed by an exposure of twenty-four hours to 5 parts per thousand; and after one hour's exposure to 40 parts per thousand, but retained its infective properties after one hour's exposure to 5 parts per thousand.

Tuberculous sputum was disinfected after one hour's exposure to an atmosphere containing 5 parts of chlorine per thousand.

Bacterium of fowl-cholera was destroyed after exposure for twenty-four hours to a moist atmosphere containing 1 part of chlorine in 25,000.

Dr. G. M. Sternberg (*Report National Board of Health*, 1880, p. 320) tested the effect of chlorine upon dried vaccine lymph and the micro-organisms of putrid urine. Six hours' exposure of vaccine lymph, dried upon ivory points, to an atmosphere containing 1 part of chlorine in 200, was sufficient to destroy the infective property of the lymph, as tested by subsequent inoculation. In one experiment five points were exposed to an atmosphere containing 1 per cent. of chlorine; of these, four were disinfected,

while the fifth furnished a satisfactory vaccine vesicle. The failure in this case is explained by Dr. Sternberg by the assumption of an unusually thick coating of dried lymph. In these experiments, control-inoculations with non-disinfected virus from the same packages were made in all cases.

The bacteria of putrid urine were destroyed after six hours' exposure to an atmosphere containing 1 part of chlorine in 400.

Braidwood and Vacher ("Report of Life-history of Contagium," *British Medical Journal*, 1876, vol. ii.) mixed liquid vaccine virus with equal parts of liquor chlori (B.P.), and completely destroyed the infectivity of the vaccine. The time of exposure is not stated.

Dr. E. B. Baxter (*Report of Medical Officer Privy Council*, 1875) tested the effect of chlorine on liquid and dry vaccine, and on the "virus of infective inflammation." The infectivity of the latter was destroyed by the presence of 8 to 15 parts of chlorine in 10,000. The time of exposure to the action of the disinfectant is not stated. The experiments of Dr. Baxter on vaccine lymph are not detailed with sufficient exactness to allow trustworthy conclusions to be drawn. He states, however, that "unless the chlorine was present in sufficient quantity to render the lymph acid, it had no effect."

Koch, (*Mittheilungen a. d. Kais. Gesundheitsamte*, Bd. I, p. 263) found that anthrax spores lost their power of development when immersed for 24 hours in chlorine water.

Fisher and Proskauer, in addition to testing the influence of chlorine on micro-life, also exposed a number of fabrics, colored leather and wearing apparel to the action of this agent. All the colored articles were either bleached or much altered in color. They conclude their elaborate memoir with the following observation:

Disinfection with chlorine is attended by great inconvenience, on account of the rapid evolution of the gas from the chlorinated lime and hydrochloric acid when mixed, and the very irritant action of the gas upon the mucous

membrane of the larynx and of the eyes. Clothing is also liable to be discolored by the action of this disinfectant.

Bromine.—Fisher and Proskauer (*Ibid.*) also studied the effect of the vapor of bromine upon spores of bacillus anthracis, spores of garden soil bacilli, tuberculous sputum, bacillus anthracis, micrococcus prodigiosus, micrococcus tetragenus, micrococcus of erysipelas, aspergillus nigrescens, aspergillus ruber, and several other non-pathogenic organisms.

After an exposure of three hours in a dry atmosphere containing 3 parts of bromine vapor in 100, the anthrax bacillus, tuberculous sputum, and both aspergillus species were entirely disinfected. The spore-bearing organisms and the non-pathogenic micrococci retained their power of development, although generally in a diminished degree. After moistening the air in the experimental chamber to the greatest attainable degree, three hours' exposure to an atmosphere containing 1 part of bromine in 500 acted as a thorough disinfectant; if the exposure was prolonged to twenty-four hours, 1 part in 3500 was efficient. When the proportion of bromine was reduced to 1 part in 16,000, exposure for twenty-four hours failed to disinfect spore-bearing organisms.

Upon the whole, bromine did not prove as prompt a disinfectant as chlorine, besides being very difficult and dangerous to handle.

Koch (*loco cit.*) found a two per cent. aqueous solution of bromine effective against anthrax spores, after twenty-four hours' exposure.

Iodine.—The disinfecting power of iodine has been determined by Dr. G. M. Sternberg (*American Journal of the Medical Sciences*, April, 1883). He experimented upon the micrococci of pus and of septicæmia, bacterium termo, and the organisms found in broken-down beef-tea. An exposure of two hours to the disinfectant in solution, in the proportion of 1 in 500, was effective in destroying the vitality of all of these organisms.

Salmon (*Report of United States Department of Agriculture*, 1883) experimented on the micrococcus of fowl-chol-

era, and found iodine an efficient disinfectant in the proportion of 1 part in 1000.

A solution of iodine in water (strength not given) was found by Koch (*loc. cit.*) to destroy the spores of B. anthracis, after twenty-four hours' exposure.

Summing up briefly our knowledge upon this subject, the following conclusions seem to be justified :

1. Chlorine is an efficient disinfectant when present in the proportion of 1 part in 100 ; provided the air and the objects to be disinfected are in a moist state, and the exposure continues for upward of one hour.

2. Chlorine, when used in sufficient concentration to act as a trustworthy disinfectant, injures colored fabrics and wearing apparel.

3. Bromine is an efficient disinfectant in the proportion of 1 part in 500 ; provided the air be in a moist state, and the exposure continues for upward of three hours.

4. Iodine, in solution, is an efficient disinfectant in the proportion of 1 part in 500 ; the exposure continuing for two hours.

5. The use of chlorine, and in a greater degree of bromine, requires considerable experience in management ; when carelessly handled they may cause inconvenient or even dangerous symptoms in persons using them ; for these reasons they are not suitable as disinfectants for popular use.

CARBOLIC ACID.

By Charles Smart.

Carbolic acid may be said to have been recognized as an antiseptic from the time of its discovery by Runge, in 1834, in the distilate from coal-tar. This is sufficiently attested by the analogies which led to the use of the name *coal-tar creasote* and the well-known preservative action of the product from wood. In Watt's *Chemical Dictionary* we are informed concerning the properties of carbolic

acid, that "fish and leeches die when immersed in the aqueous solution and their bodies subsequently dry up on exposure to the air without putrefying." The deodorant action of the acid was recognized as due not to a destruction of the offensive products of putrefaction, as in the case of some chemicals, but to an influence on the process which gave rise to them. When this process was shown to be dependent on the development, growth and multiplication of certain bacterial forms, a destruction of their germs, or at least an interference with the conditions congenial to their growth, was of necessity assumed.

On this Prof. Lister, in 1867, based the use of the acid in Antiseptic Surgery. The success attending his method of treatment spread the fame of carbolic acid; and its known and well proved antiseptic properties led to its investure with disinfectant properties which were by no means proved. It was used largely as a disinfectant in Europe, and for several years was held in a similar high repute in this country.

The first experiments to test its value failed to distinguish between the antiseptic and disinfectant properties. As late as 1870, Grace Calvert's experiments* had a reference only to the delay in the exhalation of putrefactive odors from organic substances. Albumen and flour-paste which became offensive in five and seven days respectively, when exposed to the air, were preserved for eleven and twenty-five days when mixed with five per cent. of the acid. Even the experiments of Shroeter,† in 1878, seem mainly directed to define an antiseptic value. A liquid characterized only as teeming with bacteria, had its contained organisms rendered motionless and precipitated by the addition of 0.05 per cent. of the acid—a dilution of 1:2000. Raw flesh in a dilution of 1:10,000=0.01 per cent., began to putrefy at the end of six days; in 1:2000=0.05 per cent., the liquid, notwithstanding the presence of the flesh, remained clear and without odor for four weeks; in 1:1000=0.1 per cent., the preservation

* Chemical News, London, 1870, Vol. xxiii., p. 281.

† Beitrage zur Biologie der Pflanzen, Breslau, 1878, 3 Heft, S. 30 et seq.

was prolonged from six to eight weeks, while in 1:500= 0.2 per cent., the liquid remained clear and free from all organisms for many months. Hence he considered that a solution containing 0.1 per cent. of the acid is one in which no low organisms can exist, and that a dilution of 0.01 per cent. will retard their development for some time.

The acid was recognized as being specially destructive to the moulds, a much smaller quantity sufficing to destroy them than was requisite to insure protection from the bacteria of putrefaction. Thus, Baxter* quotes Manassein as authority for the statement that one-sixteenth of one per cent. deprived the spores of penicillium of their germinating power; and Schroeter found that the vapor of the acid arrested the development of penicillium and mucor and destroyed their spores. One thorough fumigation of a mould-infected chamber acted so radically that for six weeks afterward no trace of the fungi was discovered.

It became evident, however, to the experimenters having this matter in view, that the acid might interfere with the development of the bacteria of putrefaction without destroying their power of multiplication when transferred to a more congenial environment. Hence, culture experiments were instituted on the bacteria that had been subjected to the influence of the acid. Moreover, it was recognized that experiments on the bacteria of putrefaction were by no means satisfactory as arguments on the vitality of the disease germs which were concerned in the process of disinfection. Hence were instituted experiments on certain infective matters.

Braidwood and Vacher investigated the action of the acid on vaccine lymph in 1870, and verified their results in 1876.† On four children vaccinated with lymph containing 2.5 per cent. of acid, six vesicles were obtained at ten points of insertion. In these instances the lymph was removed from the arm, mixed in a watch glass with the acid and applied at once. A second group of children

* Report of the Medical Officers of the Privy Council and Local Govt. Board, London, 1875, p. 216 et seq.

† British Med. Association. Scientific Reports, London, 1876.

five in number, were vaccinated in a similar way ; but the mixtures used had been preserved in Husband's capillary tubes for seventeen days, three weeks, four weeks, and six weeks respectively. These inoculations all failed and the children afterward underwent a successful normal vaccination. Similar results were obtained by trying the carbolated lymph on a heifer.

Meanwhile, Dougall, in 1873, operated on vaccine lymph, making use of subsequent vaccination as the test of the action of the carbolic acid on the virus. He exposed the lymph in a bell jar of one cubic foot capacity for thirty-six hours, and after mixing it with glycerine and water, sealed it up in capillary tubes until used for vaccination. The lymph thus treated produced satisfactory vesicles. Led by this result, he then treated fresh vaccine with one per cent, of pure carbolic acid and found its infective property undiminished. But about the same time Hoppe Seyler* determined that two per cent. of the acid destroyed the activity of vaccine virus ; and two years later Baxter, in his careful work for the British health authorities, was also successful in destroying the virus, as proved by subsequent inoculation with the disinfected matter. He exposed dry vaccine to carbolic acid vapor in a bottle one-third filled with the acid and found that when the period of exposure was less than thirty minutes the infection was but slightly if at all impaired. When the exposure extended to thirty minutes, disinfection was effected in one specimen, while another produced two vesicles for three insertions. In two instances in which the exposure was prolonged for sixty minutes the virus proved inefficient when subsequently used. He also found that while the presence of one per cent. of carbolic acid in liquid vaccine exerted no influence on its activity, two per cent. destroyed its infective power with certainty.

Dougall, returning to this subject in 1879,† concluded from some of his experiments that if the vaccine were used immediately after its exposure to the carbolic acid,

* Arch. Gen., May, 1863, p. 633.

† British Med. Journ., 1879. vol. ii. p. 726.

or if hermetically sealed in the meantime, the virus would fail, but that if exposed to the air after being carbolized it would recover its activity. Thus sixty parts of vaccine and forty of acid, when used immediately after mixture, gave no results, but when used after a free exposure to the air during fourteen days, it was found to have recovered its active properties. He therefore concluded that the infected particles of the lymph became covered with coagulated albumen of the vaccine liquid, and that in vaccination the free acid coagulated the contents of the dermal capillaries and rendered absorption impossible. But these experiments of Dr. Dougall did not succeed in the hands of J. W. Miller, of Dundee.*

He prepared four specimens, each containing two parts of carbolic acid and three of vaccine. The mixtures were exposed to the air for fourteen days before use; and in each of the four experiments the lymph was barren. Two experiments were made with vaccine which had been exposed to the air for fourteen days after its admixture with five per cent of the acid; in one of these the lymph was barren, in the other an imperfect vesicle was obtained. One experiment, however, appeared to verify Dr. Dougall's results; equal parts of vaccine and glycerine of carbolic acid, after exposure to the air during fourteen days, yielded a good vesicle. But Miller was inclined to view this result with suspicion, and attributed it to pure lymph rubbed off by inadvertence from some of the other points of insertion on the child's arm.

But other liquids containing germs or infective matter were used by the investigators. Rosenbach,† in 1873, injected dogs and rabbits with unhealthy pus, to which five per cent. of the acid had been added, the general tenor of his results showing that disinfection had been accomplished. Baxter, two years later, experimented with the virus derived from the peritoneal cavity of guinea-pigs that had succumbed to infective peritonitis. The length of time during which the virus was exposed to

* Med. Record, Sept., 1873, p. 427.

† Practitioner, Sept., 1884, p. 146.

the action of the acid varied from thirty minutes to three hours, thorough admixture having been effected in the meantime. In one set of experiments, two per cent. and one per cent. of the acid destroyed the infection, as the animals inoculated with the mixture did not suffer. In a second series of experiments, one per cent. was efficient for protection, but with a virus containing only 0.5 per cent., the animal died in forty hours from acute cellulitis. In a third series, one per cent. was efficient, but death occurred with 0.5 per cent. in eighteen hours. In the fourth series, one per cent. proved again protective against the infective material. Similar inoculation experiments with the virus of glanders showed that two per cent. of carbolic acic destroyed its infection, while 0.5 per cent failed to act as a disinfectant.

By culture-experiments, Sternberg, in 1883,* showed that the micrococcus of pus has its vitality destroyed so that it fails to develop when introduced into a sterilized bouillon after an admixture of two hours with 0.8 per cent. of the acid, while with 0.5 per cent. its subsequent cultivation was successful; and that the micrococcus of septicæmia is destroyed by 0.5, but not by 0.25 per cent. This defines the germicide limits of the acid in respect to these organisms. On the other hand, when carbolic acid was added to the sterilized culture-liquid, a much smaller percentage than was needful for a germicidal action sufficed to prevent the development of the micrococci of pus and of septicæmia when implanted for cultivation. Thus, 0.2 per cent. prevented the development of the organisms, while 0.1 per cent. failed to protect the culture-liquid from its attack. Similar results were obtained with the micrococcus of septicæmia. This defines the antiseptic limits of the acid in respect to these organisms.

Baxter was of opinion that the length of time during which the acid was permitted to act upon the infective material was of no importance, provided that thorough mixture was insured. This implies a belief in the instan-

*Amer. Journ. Med. Sciences, April, 1883.

taneous action of the acid on the active principle of the virus. Some experiments by Koch* in 1881, Salmon† in 1883, and Schill and Fisher‡ in 1884, indicate that time of exposure, as well as strength of solution, enters as an element into the question of disinfection. Thus the last-mentioned investigators, operating on fresh tubercular sputa, found that disinfection was accomplished by treatment with three, two, or even one per cent. of acid for twenty hours; but that five per cent. failed to disinfect when the period of digestion was limited to two hours. Post-mortem examinations discovered sound organs in the animals inoculated with the former mixtures, and tubercular disease in those of the specimens treated with the latter and stronger mixture. Salmon, operating on the micrococcus of fowl cholera, obtained the destruction of the virus by one per cent. of the acid, the test being inoculation. In some experiments in which the test was cultivation, one per cent. succeeded and 0.5 per cent. failed to destroy the power of germination when the digestion with the acid was continued for one and a half hours; but 0.5 per cent. was successful when the digestion was prolonged for twenty-four hours.

The bacilli and spores of anthrax have been subjected to a number of experiments, of which those of Davaine§ are the earliest. The blood of an infected animal, diluted with one hundred parts of water, was used. This was found to be speedily fatal to guinea-pigs when injected under the skin, but its virulence was destroyed on treatment for an hour with one per cent. of carbolic acid. Koch found that the *spores* of anthrax had their vitality destroyed by immersion for twenty-four hours in a five per cent. aqueous solution of the acid. A two per cent. solution was not efficacious; but after five days' digestion in this solution the development of the spores was somewhat retarded. Further experiments showed entire failure of disinfection with a one and two per cent. solu-

* Mitt. a. d. Kais. Gesundheitsamte, 1881, vol. i.

† Report Dept. Agriculture, U. S., 1883.

‡ Mitt. a. d. Kais. Gesundheitsamte, 1883, vol. ii.

§ Comptes Rendus, Oct. 13, 1873.

tion : success after seven days with three per cent. ; after three days with four per cent., and after two days with a five per cent. solution. Culture in gelatine was the test employed in these instances. On the other hand, the *bacilli* were destroyed by exposure of from two to twenty-five minutes in aqueous solutions containing from five to one per cent. of the acid, the test being culture in solidified blood-serum. The culture in gelatine of the anthrax *spores* was not prevented by their antecedent immersion for one hundred and ten days in oil containing five per cent. of the acid nor by seventy days in alcohol of the same carbolic strength. An oleaginous five per cent. solution diminished the development of the *bacilli* in three or four days, and accomplished disinfection on the sixth day, as shown by the failure of subsequent efforts at cultivation. Even a one per cent. solution in oil destroyed their power of development on the sixth day, but it is to be observed that a similar result followed the use of pure olive oil. Arloing, Cornevin and Thomas* found that the virulence of anthrax spores persisted after an immersion of forty-eight hours in alcohol containing two per cent. of the acid, while it was destroyed by the action of the same percentage in water. Blyth† also experimented with these spores. He showed the inefficiency of the carbolic acid powders—Calvert's, Jeyes' and McDougall's. The spores invariably developed notwithstanding contact with the powder for twenty-four hours. A one per cent. carbolic solution had no effect on their development : five per cent. retarded their growth ; twenty-five per cent. in alcohol rendered them incapable of germinating in broth.

While these investigators were testing the power of carbolic acid on certain disease-producing substances, many series of experiments were performed on the bacteria of putrefaction, with a view of determining the germicidal as well as the antiseptic powers of the acid on the organisms, the latter being expressed by the quantity of

* Comptes Rendus Soc. de Biolog. Septieme serie, t. iv.

† Med. Times and Gaz., Oct. 11, 1884, p. 498.

acid required to be added to a nutritive liquid in order to restrain their growth, and the former to prevent them from multiplying when subsequently transferred to a suitable culture-liquid.

Baxter's experiments showed that 0.5 and 0.1 per cent. were required for the germicidal action, the larger percentage being requisite when the liquid was albuminous. Hamlet* operating on Pasteur's liquid containing B. punctum, B. termo and M. crepusculum, found a slight diminution in the number of moving bacteria after standing five days mixed with one per cent. of carbolic acid, while with five per cent. few of the bacteria showed signs of movement. Nevertheless, in this last experiment their vitality persisted, for when a little of the solution was transferred to a large quantity of Pasteur's liquid, the whole was in two days teeming with bacteria. Notter's † results were to the effect that 3.3, 5 and 6 per cent. of carbolic acid did not destroy the movements of the bacteria in a putrid infusion of beef, even after the lapse of seven days. Jalan de la Croix‡ found that when two drops of a liquid teeming with bacteria are added to a sterilized meat-juice, the acid must be present in the proportion 1 : 669 to prevent development; but to produce a germicidal effect in this weak bacterial liquid, acid in the proportion 1 : 22 had to be added. The bacteria in broken-down meat infusion were killed by immersion for twenty-four hours in a solution of 1 : 22, although not in 1 : 42; but to prevent the development of germs when this liquid was introduced into a sterilized infusion it was necessary to give them a preparatory soaking for twenty-four hours in an acid of the strength 1 : 2.66, for a solution of 1 : 4 did not deprive them of their fecundity. To prevent the decomposition of boiled meat juice by germs falling into it from the air 1 : 402 was required; but for an unboiled infusion 1 : 502 sufficed; and to prevent the development of the germs in the former when transferred to a sterilized liquid, 1 : 22 was required, while those in the latter

* Jour. Chem. Soc., London, 1881, xxxix, p. 326.

† Dublin Journ. Med. Sciences, 1879, Vol. 68, p. 196.

‡ Arch. fuer Experimentelle Pathologie, Leipzig, 1881, p. 175 et seq.

were not deprived of their germinating power by 1 : 10. Vallin* justly remarks of De la Croix's experiments, that they must be accepted with some reserve, since it is contrary to the general experience that a boiled liquid should require more of an antiseptic to preserve it than one which had not been boiled. Sternberg found that 0.2 per cent. was antiseptic in view of B. termo. but one per cent. was required for action as a germicide. He further found that the bacteria in broken down beef-tea retained their vitality after an exposure of two hours to a four per cent. solution.

Turning from these experiments in which the carbolic acid was used in the form of liquid to those in which its vapor was employed, we find the following. in addition to those already mentioned in connection with antiseptics, the destruction of moulds. and of the vaccine efficiency.

Perrin and Marty† failed to prevent the decomposition of barley-water, milk, blood, urine, etc.. by the atomization of a five per cent. carbolic liquid. Schotte and Gärtner‡ volatilized carbolic acid by heat in a closed chamber in which were exposed to the action of the vapor liquids containing bacteria and woolen cloths that had been dipped in these liquids. determining at the close of the exposure whether the fecundity of the bacteria had survived by transferring them to a sterilized culture liquid. For efficient disinfection rapid evolution of the carbolic vapors was required. The bacteria in the exposed liquids were destroyed by the diffusion of 7.5 grammes of carbolic acid per cubic metre, but those in the inpregnated cloths required a stronger diffusion, 12.5 grammes, when the fabrics were damp, and 15 grammes when they were dry.

From a survey of these experiments on carbolic acid performed since the introduction of methods of percision in testing germicidal or disinfectant properties the value of the acid in these respects may be determined.

---

* Traité des Désinfectants et de la Désinfection, Paris, 1882, p. 163.

† Bulletin de la Soc. de Chir., 1879, t. v. p. 153.

‡ Deutscher Verein fur Oeffentliche Gesundhpflege, 1880, t. xii, p. 337 et seq.

One per cent. in an aqueous solution has destroyed with certainty the virulence of septic and purulent matters, of the tubercle bacillus, and of the micrococci of fowl cholera; some of the organisms related to putrefaction have also been destroyed by solutions of this strength. But to produce these results in some instances the contact with the disinfectant had to be continued for many hours. Two per cent. of the acid in an aqueous solution was required to destroy the infection of vaccine and glanders; but some of the experiments on the former seem to indicate that no destruction of the virus was effected, but merely a suspension of its powers, which were recovered on the dissipation of the acid by subsequent prolonged exposure to the air. The spores of anthrax did not lose their ability to germinate unless treated with a five per cent. solution for twenty-four hours or with a weaker solution for a longer time. Lastly as showing how little reliance can be placed on carbolic acid as a disinfectant except in special instances, as in those above mentioned where its effects have been determined, the organisms in broken-down beef-tea were not deprived of their reproductive powers by treatment with four per cent. acid, Sternberg, nor with six per cent., Notter, nor with ten per cent., De la Croix; the last observer indeed asserts that about thirty per cent. (1 : 2.66) was needful to effect this object.

The large percentage of the acid required for disinfectant or germicidal action when applied directly in the liquid form, prepares us for its failure when used in the form of vapor. Douglas and Baxter, from the results of their experiments on vaccine concluded that aërial disinfection by carbolic acid vapor was practically impossible. The atomizer, however, offered better facilities for the diffusion of the vapor and Strott* in 1876, and Wernich† in 1883, recommended the use of the spray as protective against albuminoid contagious principles. But the experiments of Perrin and Marty and of Schotte and Gartner demonstrated its inutility as against bacterial life.

* Ventilation und Desinfection der Wohnraume, Holtzminden, 1876, p. 19.

† Real-Encyclopadie der Gesammten, Heilkunde, 1883, B. 15, S. 170 et seq.

The valuable antiseptic properties of the acid do not come within the scope of this article, although they have been in a measure indicated incidentally.

DISINFECTION WITH MINERAL ACIDS.

By Victor C. Vaughan.

Disinfection with mineral acids in one form or another has long been practiced. Sulphurous acid was used by the ancient Greeks in the purification of their temples after sacrificial offerings had been made. In 1773, Morveau recommended the vapor of hydrochloric acid produced by the action of sulphuric acid on sodium chloride. In 1780, Smyth began the use of nitrous acid vapor as a disinfectant. During the present century, many experiments have been made for the purpose of determining the value of the mineral acids as disinfectants, both in liquid and in vapor form. It is the purpose of this paper to review briefly these reports, and to ascertain what conclusions may be drawn therefrom. Since sulphurous acid will be discussed in another paper, no further mention will be made of it here.*

Hydrochloric Acid.—Dougal† found that vaccine virus exposed under a bell-jar of a cubic foot capacity, for twenty-four hours, to the vapor of the acid became inert. After exposure the lymph was mixed with glycerine and water, and the reaction of the mixture (acid) was noted. The mixture was then hermetically sealed in tubes, and so kept until used. Dr. Dougal believed that the effectiveness of the vapor was due to its rendering the virus acid. In proof of this he gives the following tabular statement of the reaction of the lymph and glycerine mixture used in his successful and unsuccessful vaccinations after exposure to different agents:

*See papers by Drs. Sternberg and Raymond in this series of reports.

† Glasgow Med. Journal, vol. 5, p. 166.

Successful vaccination. Virus not destroyed.	Reaction of the lymph and glycerine mixture	Vaccination not successful. Virus destroyed.	Reaction of the lymph and glycerine mixture.
Carbolic acid vapor.	Neutral.	Chloride of lime.	Acid.
Carbolic acid.	"	Sulphurous acid.	"
Chloroform.	Alkaline.	Nitrous acid.	"
Camphor	"	Glacial acetic acid.	"
Sulphuric ether.	"	Hydrochloric acid.	"
Iodine.	Neutral.		

Commenting upon the above table, Dr. Dougal states: "These results *per se* are singularly and suggestively explicit. They show that the mixture of lymph and glycerine of the successful vaccinations was either neutral or alkaline; while that of the unsuccessful was, without exception, acid. Hence, volatile acids, or a volatile body causing acidity by chemical affinity, as the chlorine from the chloride of lime, which produces hypochloric acid and free oxygen, are the best destructives of the active properties of vaccine lymph, and therefore *a priori* of variolous matter and other zymotica.* The same theory is insisted upon by Dr. Dougal in a later paper.† Results with hydrochloric acid vapor similar to those obtained by Dougal, were reached by Braidwood and Vacher in eight experiments.‡

Koch§ ascertained by cultivation that anthrax spores were destroyed after ten days' exposure to a two per cent. solution of the acid; but that exposure from one to five days failed to destroy the spores.

Dr. Sternberg, in some experiments made for this report, found hydrochloric acid to fail as a disinfectant when u sed in ten per cent. solution, and to be successful when the strength was increased to fifteen per cent. Each c. c. of the acid used by Dr. Sternberg contained 0.395 gramme of HCl.

* Loc. cit., p. 168.

† British Med. Journ., Vol. ii, p. 726, 1879.

‡ Life History of Contagium.

§ Mittheilungen a. d. Kais. Gesundheitsamte, B. I. S. 263.

Sulphuric acid.—Koch* noticed diminished development of anthrax spores after exposure to a one per cent. solution of sulphuric acid for twenty days. The test was by cultivation. Salmon,† experimenting upon the micrococcus of fowl-cholera, found one-half per cent. solution of sulphuric acid successful as a disinfectant, tested by inoculation; but one-fourth and one-eighth per cent. solutions unsuccessful, tested by cultivation. Sternberg‡ states that "sulphuric acid destroys B. termo and the two species of micrococcus experimented upon in the proportion of 1:200; but a four per cent. solution failed to destroy the bacteria in broken-down beef-tea (old stock), doubtless because of the presence of reproductive spores. The multiplication of the bacteria mentioned was prevented by the presence of this acid in a culture solution of 1:800." Dr. Sternberg has given the per cent. of sulphuric acid necessary to insure disinfection at eight. Each c.c. of the acid used contained 1.480 gramme H_2SO_4.

Nitrous acid. Dougal§ found that vaccine lymph exposed to nitrous acid under a bell-jar of one cubic foot capacity for twenty-four hours, was rendered inert. The lymph was treated as given under hypochloric acid, and the action was supposed to be due to rendering the lymph acid.

Notter‖ has experimented upon nitrous acid as an aerial disinfectant. However, his conclusions are not wholly trustworthy, as he considered the bacteria destroyed when their motion was only arrested. He says: "I believe the full effect of the agent to be produced when there is arrest of motion, with complete precipitation and disorganization of the bacteria, and I have endeavored in each case to look for this result. One hundred c.c. of putrid beef infusion in saucers were placed in a chamber, of a cubic capacity of fifty-three feet, with two ounces of copper wire, and fifty c.c. of concentrated nitric acid, yield-

* Loc. cit., p. 264.
† Report Dept. Agriculture, 1883.
‡ Bacteria p. 233.
§ Loc. cit.
‖ Dublin Journ. Med. Sciences, vol. 71, p. 508.

ing 0.35 per cent. of nitrous acid. Soon the bacteria became less active, and in forty-eight hours the activity was still further diminished, and a heavy precipitation of the organisms was noticed. The infusion was free from odor. On the third day there was no tendency to the further development of the bacteria and the liquid was quite inodorous. At the end of a week there was no further decomposition and the infusion was found to be strongly acid.

Sternberg* found that exposure of vaccine virus for six hours to an atmosphere containing one per cent. of nitrous acid vapor, destroyed the germs; also that the bacteria of putrid urine were destroyed when exposed on filter paper for six hours to an atmosphere containing one-half per cent. of nitrous acid gas.

Nitric acid.—Dr. Sternberg has ascertained that nitric acid fails as a disinfectant in solutions of five per cent., but is effectual in solutions of eight per cent. Each c.c. of the acid used contained 0.819 gramme of HNO_3.

Chromic acid.—Koch† ascertained that anthrax spores were destroyed by exposure to one per cent. solutions of chromic acid after from one to two days.

Osmic acid.—Koch‡ found by cultivation that anthrax spores were destroyed by exposure for twenty-four hours to one per cent. of osmic acid.

Practical considerations of the use of the mineral acids as disinfectants. The action of ten and five per cent. solutions of sulphuric, nitric and hydrochloric acids upon lead pipes was tried with the results given in the accompanying table. Weighed pieces of lead pipe were placed in the dilute acids, and the loss was determined by subsequent weighings. This represents a more powerful action than would result simply from the rapid passage of the disinfectant through the pipes; but the table gives results which would be obtained by the solution standing in a trap. At the time of each weighing, the dilute acid was replaced by a fresh portion.

* National Board of Health Bulletin, p. 287.

† Loc. cit., S. 264.

‡ Loc. cit.

Date of weighing and changing solution.	No. of days in the solution.	10 per cent. H_2SO_4		5 per cent. H_2SO_4		10 per cent. HNO_3		5 per cent. HNO_3		10 per cent. HCl		5 per cent. HCl	
		Weight of pipe.	Loss.	Weight of Pipe.	Loss.	Weight of pipe.	Loss.	Weight of pipe.	Loss.	Weight of pipe.	Loss.	Weight of pipe.	Loss.
		Grams.	Grams.	Grams.	Grams.	Grams.	Grams	Grams.	Grams.	Grams.	Grams.	Grams.	Grams.
Jan. 30, 1885.	0	53.120	. .	52.990	. .	53,000	. .	53,000	. .	53,000	. .	53,000	. .
Feb. 2, "	3	53.120	00	52.990	00	48,500	4,500	51,300	1,700	52,930	0.070	52,990	0 010
Feb. 3, "	1	53.120	00	52.990	00	44,220	4,280	49,350	1,880	52,900	0.030	52,970	0.020
Feb. 4, "	1	53 120	00	52.990	00	41,130	3,090	47,365	1,985	52,860	0.040	52,925	0.045
Feb. 6, "	2	53.120	00	52 990	00	34,520	6,6 0	44,400	2,9o5	52,845	0.015	52,920	0.005

The experiments were continued until the nitric acid had completely destroyed the pipe; but as the results are sufficiently shown by the above figures, it is unnecessary to give the table in full. After a number of days there was a slight increase in the weight of the pipes placed in the sulphuric acid solutions. All the acids used were of the commercial grade. We also have figures showing the action of the dilute acids upon iron pipes; but as this action is rapidly destructive with all the acids, it is unnecessary to give the figures. In order of disintegrating effects upon iron pipes, sulphuric acid acts with most vigor; while there is not much difference in the effects produced by the same strength solutions of nitric and hydrochloric acids. The action upon zinc is in the same order as that given for iron; while the solvent action of nitric acid on tin was found to be greater than that of either sulphuric or hydrochloric acid.

THE METALLIC SULPHATES.

By George M. Sternberg.

The metallic sulphates have been largely recommended as "disinfectants," and directions for their use are to be found in the printed circulars of health authorities in this country and in Europe. In France the sulphate of copper is a favorite disinfectant, and, as I shall shortly show, is a reliable agent for the destruction of germs in the absence of spores. It is very much superior to ferric sulphate or zinc sulphate, which have been more extensively used in our own country.

The value of all these agents as antiseptics is beyond question, and when the object in view is to prevent the development of germs in privy-vaults, cesspools, etc., a solution of "copperas," on account of its cheapness and efficiency, is especially to be recommended. But the directions often given for the use of dilute solutions of ferric sulphate or zinc sulphate, for the disinfection of the

sputa of patients with diphtheria, the excreta of patients with cholera, typhoid fever, etc., are founded upon a mistaken estimate of the germicide power of these salts.

The metallic sulphates have all a certain value for the prevention of putrefactive fermentation, and for neutralization of the volatile products of putrefaction. They are therefore "disinfectants" in the popular acceptation of the term. Thus Vallin says :

"*Metallic sulphates in general.*—These agents are disinfectants in the vulgar sense of the word ; they diminish, or cause to disappear, bad odors ; their action being limited to the neutralization of ammonia and the decomposition of sulphuretted hydrogen, or of the sulph-hydrate of ammonia.

"In this group are the soluble salts of iron, of zinc, of copper, of manganese and of lead. The oxides of these metals, which are quite cheap, have also been recommended for this purpose ; but the salts have the advantage over the oxides of being able to saturate ammonia already formed, or that which results from the decomposition of the sulph-hydrate of ammonia ; the oxide of iron, for example, can only fix sulphuretted hydrogen by forming the sulphuret of iron ; the sulphate of iron produces in addition the sulphate of ammonia.

"These salts, then, cannot neutralize all bad odors, and therefore they do not entirely merit the title of deodorants. Bad odors, indeed, owe their infection to a great quantity of diverse substances which have not been completely determined by chemistry, and of which scatol is one of the most recently discovered. It is, then, almost entirely the two badly smelling compounds which have been longest known, which are neutralized by these metallic salts."*

"Virchow has pointed out one of the objections to the use of the sulphate of iron for disinfecting feces. The volatile fat acids, butyric, valerianic, etc., which have a disgusting odor and are highly toxic, are ordinarily combined with ammonia. When we throw sulphate of iron upon fecal matter, the sulphuric acid combines with the ammonia, and fetid products are given off, which are very volatile.

"The immediate effect, therefore, of throwing sulphate of iron into latrines, is frequently to augment the bad

* Traité des Desinfectants, p. 57.

odor, which, however, soon diminishes, but ordinarily reappears after some time." (Op. cit., p. 63.)

In what follows we shall endeavor to fix the value of the metallic sulphates as *disinfectants*, in accordance with the definition of the term heretofore given by the Committee on Disinfectants, *i. e.*, the germicide value as fixed by biological tests.

Ferric Sulphate.—In the writer's experiments published in the *American Journal of the Medical Sciences* (April, 1883), it was found that a saturated solution of ferric sulphate failed to destroy the growing power of any of the test organisms, the time of exposure being two hours. A recent experiment upon a micrococcus obtained from the pus of an acute abscess gave a similar result. The organism grew freely in culture solutions, after exposure for two hours to a ten per cent. solution.

According to Arloing, Cornevin and Thomas, exposure to a twenty per cent. solution for forty-eight hours does not destroy the virus of symptomatic anthrax. The vitality of anthrax spores is not destroyed by exposure for six days in a five per cent. solution (Koch).*

Zinc Sulphate.—In the writer's experiments, reported in the *American Journal of the Medical Sciences* (l. c.), a solution of twenty per cent. of this salt failed to destroy the micrococcus of pus. In experiments recently made, the same micrococcus grew after exposure to a ten per cent. solution for the same time (two hours), but development was somewhat retarded. Another micrococcus (*M. tetragenus*) was destroyed by a ten per cent. solution in the same time. Broken-down beef-tea, mixed in equal quantities with a forty per cent. solution, was not sterilized at the end of two hours, as shown by culture experiments made in the usual way.

Koch found (l. c.) that a five per cent. solution had not destroyed the growing power of anthrax spores at the end of ten days, although their development was somewhat retarded.

* See table on p. 264 of the first volume of the Mittheilungen aus dem Kaiserlichen Gesundheitsamte.

Cupric Sulphate.—I have recently made experiments with this salt upon pure cultures of *B. anthracis* and of *B. subtilis*, and find that in a twenty per cent. solution (equal parts of a forty per cent. solution and of the culture) it fails to destroy the vitality of the spores of these bacilli in two hours' time.

Arloing, Cornevin and Thomas found that the dried virus of symptomatic anthrax is destroyed in forty-eight hours by a solution of this strength (twenty per cent.). Koch found (l. c.) that a five per cent. solution did not destroy the vitality of anthrax spores at the end of ten days, although the rapidity of development was somewhat retarded.

The germicide power of this salt, is, however, decidedly superior to that of the corresponding salt of iron or of zinc. I have demonstrated by recent experiments that it destroys micrococci in the proportion of 0.5 per cent. (=1 : 200). The experiments were made upon a micrococcus derived from the pus of an acute abscess, and upon the micrococcus of swine plague. In one-half the amount named (1 : 400) it failed to destroy the vitality of these micrococci.

This agent, then, is a valuable germicide, and may be safely recommended for the disinfection of material not containing spores. But none of the metallic sulphates can be relied upon for the destruction of spore-bearing pathogenic organisms, and the germicidal power of ferric and zinc sulphate is too feeble to make these salts available for disinfecting purposes, even in the absence of spores.

ZINC CHLORIDE.

By George H. Rohé.

In his classical essay on disinfection,* Koch expresses astonishment that an agent, which proved almost entirely inefficient as a germicide in his experiments, should have

*Ueber Desinfection: Mittheilungen a. d. Kais. Gesundheitsamte. Bd. I. S. 261.

obtained the widespread reputation as a disinfectant which chloride of zinc enjoys. He shows that anthrax spores, exposed to the action of a five per cent. solution (1:20) of this salt for thirty days, germinated as freely upon a suitable culture medium as similar material not so exposed. The development of micrococcus prodigiosus was only slightly retarded by exposure for upward of sixteen hours to a one per cent. (1:100) solution. Anthrax spores developed freely in a one-tenth per cent. (1:1000) solution of this salt.

Mr. A. W. Blyth* says a one per cent. (1:100) solution seemed to stimulate the growth of anthrax spores; five per cent. (1:20) failed to destroy their vitality; while twenty-five per cent. (1:4) seemed to arrest the life of the spores.

Dr. Sternberg† found two per cent. (1:50) destructive to the micrococcus of gonorrhœal pus; while one-half per cent. (1:200) destroyed the power of development of the septic micrococcus. In Sternberg's later experiments‡ ten per cent. of Squibb's liquor zinci chloridi (said to contain fifty per cent. of anhydrous chloride of zinc) was found effective in destroying the organisms of broken-down beef-tea. Numerous experiments have shown that these organisms are fully as resistent to most germicides as are the spores of B. anthracis. In order to clear up the apparent discrepancy between these observations of Koch and Sternberg, an additional series of experiments has recently been made by the latter, assisted by Dr. A. C. Abbott. These experiments showed that the spores of B. anthracis are not killed by an exposure for two hours to a ten per cent. (1:10) solution of this salt. A five per cent. (1:20) solution, acting for the same period was, however, effective in destroying the spores of B. subtilis, and upon broken-down beef-peptone solution, which had been freely exposed to the air, and consequently contained a variety of microörganisms. A two and a half per cent. solution (1:40) failed to sterilize putrid beef-peptone solution.

* Medical Times and Gazette, Oct. 11, 1883.

† Am. Journ. Med. Sciences, April, 1883, p. 331.

‡ The Medical News, Feb. 7, 1885.

The above experiments indicate that zinc chloride, in the proportion of five per cent. added to the material to be disinfected, can be relied upon for the destruction of micro-organisms in the absence of spores. To destroy the vitality of anthrax spores, however, a twenty per cent. solution is necessary.

MERCURIC CHLORIDE.

By George M. Sternberg.

The use of corrosive sublimate as a parasiticide and as an antiseptic agent for the preservation of animal tissues, etc., has long been known ; but the researches which have established its value as a disinfectant are of comparatively recent date. These researches, made during the past four or five years, have demonstrated that bichloride of mercury occupies a leading place among known germicide agents. Miquel places mercuric iodide above the chloride as an antiseptic, and it may be that it has a correspondingly greater germicide value. But from a practical point of view the chloride must still be accorded the first place on account of its cheapness and solubility.

My own observations are in accord with those of Koch, of Jalan de la Croix, and others, as to the power of this agent in dilute solutions (1:1,000 to 1:10,000) to destroy the spores of bacilli—*B. anthracis* and *B. subtilis*—and this constitutes the most difficult biological test known. Micrococci and bacilli in active growth, without spores, are killed by much weaker solutions (1:20,000 to 1:40,000).

Klein, of London, is, so far as I know, the only author who has reported results in conflict with these. In his recent work on *Micro-organisms and Disease*,* he says :

"By sowing any micro-organism in a nourishing medium, to which has been added a certain substance (*e.g.*, carbolic acid to the amount of one per cent.), and exposing this medium to the conditions of temperature, moist-

* The Practitioner, Lond., Oct. 1884, p. 251.

ure, etc., otherwise favorable to the growth of the organism, if we find after the lapse of a due period the growth is retarded or altogether inhibited, the conclusion is drawn that this substance (viz., the carbolic acid of 1 per cent.) is an antiseptic. There is nothing more fallacious than this mode of reasoning; a great many micro-organisms can be exposed to a 1 per cent. solution of carbolic acid for hours without in the least being affected, for on being transferred to a suitable nourishing medium they grow and thrive well. Similarly, by placing the spores of Bacillus anthracis in a proteid medium containing perchloride of mercury of the strength of 1 in 300,000, it is found (as Koch has shown) that the spores are absolutely incapable of germinating. But if from this the conclusion is drawn that perchloride of mercury of the strength of 1 in 300,000 is a germicide, I should most strongly dissent, for perchloride of mercury, even of the strength of 1 per cent., is not a germicide any more than vinegar; for on placing the spores of Bacillus anthracis in a proteid medium, to which so much vinegar or any other acid has been added as makes it decidedly acid, it will be found that the spores do not germinate."

I have recently had occasion to object to the use of the terms antiseptic and germicide as synonymous, and the confusion resulting from such a misuse of the term *antiseptic* is exemplified in the above quotation. No one familiar with the present state of knowledge upon the subject would think of inferring that mercuric chloride is a germicide in the proportion of 1 : 300,000, because anthrax spores do not germinate in culture-fluids containing this amount. But an agent which prevents the development of putrefactive bacilli is an antiseptic, for putrefactive decomposition is prevented by such an agent as well as by one which kills germs. A germicide is necessarily an antiseptic, but an antiseptic is not necessarily a germicide. Thus alcohol, chloride of sodium, borax, sulphate of iron, and many other agents constantly used as antiseptics, do not in the most concentrated solutions destroy the vitality of the spores of bacilli, and consequently are not germicides.

The statement made by Klein that "perchloride of mercury even of the strength of 1 per cent. is not a germicide any more than vinegar" is opposed by the experimental

evidence reported *in detail* by Koch, and by my own extended experiments with this agent. I am convinced that there must have been some defect in Klein's method of working, and that the spores which killed his guinea-pigs had not been fairly exposed to the action of the disinfecting agent. He says :

"I have tried the action of a number of substances in common use as antiseptics (*e. g.*, Calvert's fluid, pure terebene, phenol 10 per cent., perchloride of mercury 1 per cent.), on the spores of Bacillus anthracis, exposing these in comparatively large quantities to the above fluids (the two being well mixed) for twenty-four hours, and then inoculating guinea-pigs with them (spores and antiseptic.) The animal died with symptoms of typical anthrax, the blood teeming with the Bacillus anthracis."*

The very definite evidence from various sources, a portion of which will be given below, as to the power of mercuric chloride to destroy the spores of anthrax in much weaker solutions than that used by Klein, and in a much shorter time, justifies the suspicion that these guinea-pigs died from accidental inoculation with spores not subjected to the action of the disinfectant. This suspicion is further justified by Klein's account of the frequent accidents of this kind which have occurred in his laboratory. Among other examples of this given in the work already referred to is the following :

"Another gentleman working in the laboratory of the Brown Institution intended to inoculate several guinea-pigs with human tubercles. For this end he mashed up in a saline solution, in a clean mortar, a bit of human lung studded with tubercles. He did this in my room on the same table on which I was working with anthrax. One of these guinea-pigs, inoculated with human tubercle, died before the second day was over of typical anthrax. Its blood was teeming with the Bacillus anthracis. Such an accidental anthrax in guinea-pigs inoculated with tubercle occured several times. . . I myself had the following accidental contaminations." . . .†

We are not here directly concerned with the restraining influence of mercuric chloride upon the development of

* Op. cit., p. 253.

† Micro-organisms and Disease. The Practitioner, London, Aug., 1884, p. 110.

anthrax spores, but having made some recent experiments in this direction which fully confirm the results previously reported by Koch, I may be excused for referring to the matter, especially in view of the therapeutic and sanitary possibilities which suggest themselves in connection with this inhibiting action of corrosive sublimate in very dilute solutions. From a sanitary point of view, it is evident that an agent which is capable of preventing the development of disease germs in cess-pools and privy-vaults in the proportion of 1 : 300,000 [*i. e.*, one pound costing fifty cents would inhibit the development of anthrax spores in 300,000 pounds of a suitable culture-fluid] has an interest for health officers quite independent of the interest which attaches to it as a potent germicide in stronger solutions.

Experiment, *Dec.* 22, 1884.—Mercuric chloride was added to a sterilized culture-fluid in the proportion of 1 : 100,000, 1 : 200,000, and 1 : 400,000, and two culture-flasks were filled from each solution. These flasks were then inoculated with anthrax spores from a pure culture, and another flask not containing the mercuric chloride was inoculated to test the stock. At the end of 24 hours the last-mentioned flask contained an abundance of anthrax filaments, the others remained clear. At the end of 48 hours the two flasks containing the bichloride in the proportion of 1 : 400,000 contained flocculi of anthrax filaments, and the others remained clear.

Davaine found that the virulence of serum containing anthrax bacilli, obtained from the subcutaneous cellular tissue of an animal recently dead, is destroyed by adding to it corrosive sublimate in the proportion of 1 : 150,000.* In this case no spores are present in the material.

The restraining power of this agent is not so great for the spores of *B. subtilis* as for those of anthrax. This was shown by an experiment made upon the same date as that above reported. At the end of 24 hours after inoculation with spores, a mycoderma of *B. subtilis* had formed in

* Recherches sur le traitement des maladies charbonneuses chez l'homme. Bulletin de l'Acad. de Med., 17 Juillet, 1880, p. 557.

solutions containing 1 : 100,000, and in 48 hours the same results had occurred in two flasks containing 1 : 50,000.

The inhibiting power of this agent is still less for micro-organisms in active multiplication. Thus, in my experiments reported in the *Am. Journal of the Med. Sciences*, April, 1883, the development of micrococci was prevented by 1 : 30,000 to 1 : 40,000. I have recently repeated these experiments with a similar result. To destroy the vitality of the same micrococci, as proved by their failure to grow in culture fluids required 1 : 20,000, while the bacteria in broken-down beef-tea, containing spores, were destroyed by 1 : 10,000. According to Koch, mercuric chloride in the proportion of 1 : 1,000 destroys all spores in a few minutes, and in weaker solutions—up to 1 : 10.000—he has shown by culture and inoculation experiments that this agent destroys the vitality of anthrax spores.

The results of his culture and inoculation experiments are not, however, entirely in accord, and it seems probable that failure to develop upon the surface of a solid culture-medium after ten minutes' exposure to 1 : 20,000 may have been due to the restraining influence of a small amount of bichloride not removed by the washing in alcohol which was resorted to for the purpose of getting rid of this complication. Fluid cultures possess an evident superiority for such experiments as this, for when a very small quantity of spore-containing material is introduced into flasks containing a large quantity of culture-fluid the disinfecting agent is diluted beyond any possibility of interfering with the success of the experiment. Moreover when spores fail to develop in such fluid-cultures it is easy to prove that the failure relates to loss of vitality on the part of the spores, and not to the presence of an inhibiting agent. This I am in the habit of doing by inoculating the same culture-fluid with other spores not disinfected, and the rapid development of these is satisfactory evidence that in the first experiment failure to develop was not due to the small amount of mercuric chloride introduced in the inoculation with disinfected spores.

The view that in Koch's surface-cultures the inhibiting influence of the bichloride came into play, is sustained by his own inoculation experiments and by my culture experiments reported below. Thus we are informed* that three mice were inoculated with anthrax spores, attached to strands of silk thread, which had been exposed for ten minutes to solutions of the strength of 1:10,000, 1:20,000, and 1:50,000. All of the mice died of anthrax, but while the one inoculated with the strand exposed to 1:50,000 died in the usual time—on the second day—the one inoculated with 1:20,000 did not die until the fourth day and the one with 1:10,000 not until the fifth day.

That anthrax spores may survive exposure to a solution of 1:10,000 for a longer period than ten minutes is also shown by the following experiments.

Dec. 18, 1884.—A *small quantity* of a culture-fluid containing anthrax spores was exposed for *one hour* to mercuric chloride in the proportion of 1:10,000. No development of anthrax bacilli occurred in a culture-flask inoculated with these spores, but in another experiment, made at the same time, in which the proportion of the disinfectant and the time of exposure remained the same, and in which a *much larger quantity* of the spore-containing culture fluid was used, there was an abundant development of anthrax bacilli in the inoculated culture-flask.

It is evident that in this experiment a material change in the conditions was made, although the time of exposure and the amount of the disinfecting agent present, were the same in both cases, and that in experiments of this kind the amount of material to be disinfected must also be taken into consideration. In other words, a few germs may be destroyed by a comparatively dilute solution of the disinfecting agent, while stronger solutions will be required for the destruction of a large number of germs contained in the same amount of material. Again it is true of mercuric chloride as well as of oxidizing disinfectants, such as potassium permanganate and the hypochlorites, that the quantity of non-living organic mate-

* Mitth. a. d. k. Gesundheitsamte, 1. p. 277.

rial present will also materially influence the result. This is illustrated by my experiments reported below in which semi-solid feces was the material subjected to the action of the disinfectant.

The spores of *B. subtilis* are destroyed by about the same proportion of mercuric chloride as is required to kill anthrax spores.

Experiment, Dec. 22, 1884.—A small amount of a culture-fluid containing the spores of *B. subtilis* was exposed to the action of a solution of corrosive sublimate of the strength of 1: 10,000, for thirty minutes; a like amount was exposed for one hour, and a third portion for two hours. Two culture-flasks were inoculated with spores from each. At the end of twenty-four hours those inoculated with the material exposed for thirty minutes showed an abundant development of *B. subtilis*, and the others remained clear.

The importance of the time of exposure to the action of the disinfecting agent, which is clearly brought out in the above experiment, is very well illustrated by the experiments on vaccine virus reported by Dr. W. J. Miller, of Dundee.

"I have made fourteen observations with this agent on vaccine. In one of these, it was tested in the following manner: I placed half the contents of a well-filled tube on a glass slide, and after it dried, covered it with some perchloride solution (1 in 1,000), and after allowing it to lie for ten minutes, washed off the perchloride gently with water, so that the film of vaccine remained; this was then rubbed up with water, and put in a tube for use. The product entirely failed to take, while the other half of the same specimen of lymph produced a good result. Another specimen was mixed with an equal quantity of the same solution (1 in 1,000), and was used an hour thereafter, disinfection being complete. Two trials were made with the same mixture, prepared immediately before use; two, after an interval of three minutes, and one, after fifteen minutes; and in all five, the lymph was uninjured. Five experiments were made with a solution of 1 in 500, and vaccine in equal proportions [=1: 1,000.—G.M. S.], mixed respectively, immediately before use, a few minutes, three minutes, three minutes, and five minutes;

and in all, the lymph was in no way affected. Two observations with lymph, and a still stronger solution, 1 in 250, in equal proportions, mixed immediately before use, gave the same negative result."*

According to Arloing, Cornevin, and Thomas, the activity of dried virus of symptomatic anthrax is destroyed by mercuric chloride in the proportion of 1:5,000.

Jalan de la Croix found that the bacteria in beef *bouillon* were destroyed by 1:6,500, but that the proportion required to destroy bacteria in a beef infusion made without heat was 1:2,525.

It is evident that in the absence of precise information, as to the time of exposure and other essential conditions, these results cannot be compared directly with those reported by other observers in which the material tested or the conditions of the experiment were different.

In the writer's experiments reported in the *American Journal of the Medical Sciences* for April, 1883, the bacteria in broken-down beef-tea (old-stock exposed in the laboratory for a long time) were destroyed by two hours' exposure to mercuric chloride in the proportion of 1:10,000, the amount of material exposed to the action of the disinfecting agent being comparatively small.

Extended experiments upon the disinfection of tuberculous sputum have been made by Schill and Fischer, and are reported in their paper published in the second volume of the *Mittheilungen aus dem Kaiserlichen Gesundheitsamte*. In these experiments the test of disinfection was failure of the material to produce tuberculosis when inoculated into susceptible animals.

In a first series of experiments with *dried* sputum, which had been kept for several months, a negative result was obtained in every case from the following inoculations: Two guinea-pigs inoculated with material exposed for twenty-four hours to 1:1,000; three with material exposed for twenty hours to 1:2,500; and three with material exposed for twenty hours to 1:5,000.

In another series of experiments with *fresh* sputum, in

* The Practitioner, London., Oct, 1884, p. 265.

which the sublimate solution and the material to be disinfected were used in *equal amounts*, tuberculosis resulted in all of the test-animals. Three of these were inoculated with material exposed for twenty-four hours to 1:2,000 (*i. e.*, equal parts of sputum and of a 1:1,000 solution), and three to material exposed for twenty-four hours to 1:1000.

The failure to disinfect in these experiments was probably due to the fact that the viscid mass of sputum was not penetrated throughout by the disinfecting agent. In the successful experiment with dried sputum, the amount of material used was no doubt much smaller, and its physical condition (pulverized?) such as to insure the action of the disinfectant upon every portion of it.

In a previous paper (the *Medical News*, Jan. 10, 1885, p. 34), the writer has recommended the use of a solution containing 1:500 of mercuric chloride, and 1:500 of potassium permanganate as an efficient disinfectant for sputum and for the discharges of patients with typhoid fever and cholera. The experiments of Schill and Fischer, which I had not read when this recommendation was made, indicate that it will be necessary to use some other agent when the object in view is to destroy the infective virulence of tuberculous sputum. And, in general, it will no doubt be better to use an oxidizing disinfectant, such as the hypochlorite of soda, when the germs to be destroyed are imbedded in masses of albuminous material. For such masses are disintegrated and destroyed by oxidizing agents, whereas corrosive sublimate has the opposite effect, in consequence of its power of combining with and coagulating albuminous material. For liquid fecal discharges, however, our recommendation is sustained by the experimental evidence.

The following experiments have been recently made The standard solution above referred to—mercuric chloride and potassium permanganate, of each 1:500—was diluted one-half, and mixed with an equal quantity of broken-down beef-tea (=1:2,000). After exposure for

two hours, the contained germs had lost their vitality, as proved by culture experiments.

A more difficult test was the following : The standard solution was diluted one-half, and mixed with semi-solid feces in equal quantity, well mixed by stirring. Two culture-flasks were inoculated from this at the end of thirty minutes, two more at the end of one hour, and two more at the expiration of two hours. One of the flasks inoculated at the end of an hour broke down, the others remained clear. In the case of the flask which broke down, it is probable that some little mass of material was introduced which had not been thoroughly penetrated by the disinfecting agent. When the standard solution was diluted with three parts of water, and added to an equal amount of broken-down beef-stock (=1:4,000), two hours' exposure failed to prevent the subsequent development of the contained spores in a sterilized culture-fluid.

The experimental data herein recorded seem to justify the following conclusions :

Mercuric chloride, in aqueous solution, in the proportion of 1:10,000, is a reliable agent for the destruction of micrococci and bacilli in active growth not containing spores ; and in the proportion of 1 : 1,000 it destroys the spores of bacilli, provided that the micro-organisms to be destroyed are fairly exposed to its action for a sufficient length of time.

A standard solution of 1 : 1,000 may be safely recommended for the disinfection of bedding and clothing which can be washed ; for washing the floors and walls of infected apartments ; for disinfecting the hands and instruments of surgeons and gynecologists ; and as a disinfecting wash for superficial wounds or mucous surfaces. For continuous application to wounds, etc., a solution of 1 : 10,000, or less, should be effective.

A standard solution of 1 : 500, with the same quantity of potassium permanganate, may be safely recommended for the disinfection of liquid fecal discharges, and other fluid material supposed to contain "disease germs," pro-

vided the time of exposure is not less than two hours, and the quantity of material to be disinfected is not in excess of that of the standard solution used.

CONSIDERATIONS CONCERNING THE PRACTICAL USE OF MERCURIC CHLORIDE AS A DISINFECTANT.

By Victor C. Vaughan.

Since mercuric chloride has been put forward as one of the most reliable disinfectants, its practical use has been largely discussed, and some supposed dangers in its general employment have been brought forward. It was for the purpose of ascertaining how much truth there may be in these statements that the following experiments were undertaken.

Is there danger of the passage of this highly poisonous salt from cesspools and privy-vaults, in which its use has been recommended, through the soil into wells? Sanitarians have had so much to say about well-water being poisoned by the filtration of organic matter through the soil from privy-vaults and cesspools, that it is not surprising that the above question should be asked. In order to answer it, the following experiments were made:

Experiment 1.—A large glass funnel carrying a filter-paper was filled with gravel, taken from a distance of about four feet beneath the surface. The weight of the gravel was eleven and three-fourths pounds, and, when placed in the funnel, it formed an inverted cone with a base of ten inches diameter and an altitude of eight inches. On this was poured one pint of standard solution No. 2 (corrosive sublimate and permanganate of potash, two drachms of each to the gallon of water), recommended for the disinfection of excreta. After a few minutes a pint of distilled water was also filtered through the soil. This was done in order to wash through any mercury that

might be held mechanically in the gravel. The filtrate was collected, concentrated to one fluid ounce, and tested for mercury. The result was negative. The soil retained all of the poison.

Experiment 2.—This was similar to the above, but black loam was used instead of the gravel. The weight of the soil used was seven pounds. The result was the same as with the gravel.

Experiment 3.—In this instance clay was used. The weight of the clay was nine and one-fourth pounds. As the soil in this case was very dry, it was thoroughly moistened with water before the solution of mercuric chloride was poured on.

These experiments show that the quantities of the different soils, as given above, will remove from solution and retain all the mercury contained in one pint of standard solution No. 2,—fifteen grains of mercuric chloride. That a much smaller amount of soil would accomplish the same result was shown by the following:

Experiment 4.—One and one-half pounds of gravel were placed on the filter, and one pint of standard solution No. 2—one ounce at a time—was filtered through the gravel. The filtrate contained no mercury. From these experiments it will be seen that the fear that mercuric chloride may filter through the soil, when used as a disinfectant in privy vaults and cesspools, into wells and thus poison the water, is groundless. Of course, where there is open connection between the cesspool and wells by the formation of small subterranean rivulets, there would be danger. The fixation of mercury in the soil is doubtless largely, if not wholly, due to the presence of certain inorganic salts, such as carbonates and phosphates, which form insoluble compounds of mercury.

At the recent Cholera Conference at Rome, Dr. Koch gave, as one of his reasons for not recommending mercuric chloride as a disinfectant, the belief that its disinfecting action was interfered with by the fact that it entered into combination with albuminous material, and thus failed to come into contact with germs enclosed in albu-

minous masses.* That a combination between the mercury and albumen does occur may be shown by the following very simple test :

Experiment 5.—Suspend some recently precipitated mercuric oxide in distilled water, add some egg-albumen, agitate thoroughly and filter. The filtrate is clear and colorless. Boil this filtrate with potassium chlorate and hydrochloric acid until all the organic matter is destroyed. Then test for mercury with hydrogen sulphide or stannous chloride. The mercury will be found to be present, and all that which was used as mercuric oxide can be recovered.

Albumen dissolves the oxide, forming, probably, mercuric albuminate ; but there is no reason for believing that the mercuric albuminate does not diffuse through organic matter. As shown in the experiments, it is freely soluble and readily passes through the filter-paper. It is altogether probable that it is this mercuric albuminate which forms such a powerful germicide. In this compound we have the mercury in the shape in which it would most likely be taken up by those lower forms of life which feed upon albuminous material.

Medical men have, for a long time, regarded "yellow wash" as the most successful application that could be made to syphilitic sores. Is it not likely that its great value is due to the formation of mercuric albuminate, which has a local action on the virus, and penetrates the tissue as well? A substance which is not absorbed by living organisms is not poisonous to them, and if by the formation of this mercuric albuminate the most readily absorbable form of mercury is secured, its poisonous properties are intensified.

Further considerations concerning the use of mercuric chloride will be presented as soon as some additional experiments are made. The writer is indebted to two of his students, Messrs. Wagner and Bobb, for aid in the experimental work.

* The Medical News. June 20, 1885, p. 707.

Action of Mercuric Chloride on Lead Pipes.

When a solution of mercuric chloride comes in contact with lead, there is an immediate deposit of mercury with the formation of lead chloride. That this action rapidly destroys lead pipe is shown by the following:

Experiment.—One foot of one-half inch lead pipe was placed in a tall beaker, and 1,000 c.c. of a two per cent. solution of mercuric chloride poured into the beaker. Instantaneously, a white cloud of lead chloride formed around the pipe and gradually subsided to the bottom. Each day the solution of mercuric chloride was changed and the pipe washed with water. After 4,000 c.c. of the mercuric chloride solution had been used, the pipe had worn away to such an extent, that on bending it the pipe would break.

Since the reaction is instantaneous, the result would practically be the same, though a little slower, with the solution of mercuric chloride flowing through the pipe.

Notes.—By Dr. G. M. Sternberg, Chairman of Committee.

I have recently made some experiments to determine the antiseptic power of mercuric oxide. In the proportion of 1 : 1,000 it has prevented any development of micro-organisms in veal broth, inoculated with two or three drops of "broken-down" beef-tea. In the proportion of 1 : 2,000 and 1 : 4,000, it restrained development for a time, but at the end of forty-eight hours the broth became clouded near the surface, and at the end of seventy-two hours had broken down completely. (The same culture-fluid broke down in 24 hours when not treated with an antiseptic.) This very decided antiseptic power shows that mercuric oxide is far from being "inert" from a biological point of view.

Disinfecting and Antiseptic Powder.—The powder under this name, for which a formula was given in the Preliminary Report of the Committee on Disinfectants, was withdrawn in a letter published in the *Medical News* of May 2d.

The writer was responsible for this powder, and withdrew it because of the fact that mercuric chloride is decomposed by the hypochlorites in the presence of moisture. In the powder, made as directed, this reaction does not occur, and the keeping properties of the powder are

all that could be desired. But when water is added to it the reaction occurs, and the yellow oxide of mercury is precipitated. This fact having been brought to my attention I hastened to withdraw my recommendation of the powder, although I had been much pleased with it in practical tests upon feces. Since my return from Europe I have made some additional experiments, which show that, notwithstanding the destruction of the bichloride, the powder is an excellent disinfectant and antiseptic. A sample which I have recently examined contained 2.6 per cent. of available chlorine after the precipitation of the yellow oxide by the addition of water. This same sample, after standing in an open box in the laboratory for about three weeks, still contained 1.5 per cent. of available chlorine at the bottom of the box, and 1 per cent. at the surface of the powder, which had been exposed to the air during this time. I have demonstrated, by recent experiments, that mercuric oxide is a valuable antiseptic. In the proportion of 1 : 2,000 it retards the development of micro-organisms in beef-tea inoculated with two or three drops of broken-down stock ; and in the proportion of 1 : 1,000 it entirely prevented development for a week, the duration of the experiment, while in the comparative test the beef-tea broke down in less than twenty-four hours. Nevertheless, I do not endorse the formula which I first recommended, for the reason that mercuric oxide has an antiseptic power inferior to that of the bichloride, and it is a waste of material to use the bichloride of mercury in the same formula with the hypochlorites. I would, therefore, recommend that the powder be made without the addition of mercuric chloride.

My object is to dilute the chloride of lime so that it may be used more economically, *especially upon the surface of fecal matter in privy-vaults.* Such a powder is especially needed in country places, where the old-fashioned, open privy-vaults are in use, and in garrisons and military encampments.

Chloride of lime, as received from the manufacturers, is more or less lumpy, and cannot be readily scattered about in a uniform manner. It is also much stronger in chlorine than is necessary. I have therefore, endeavored to find an inert substance suitable for diluting it.

Plaster of Paris has the advantage of retaining the chlorine better than anything else I have tried, and makes a powder which can be readily scattered about in a thin layer. Its property of setting with water is no ob-

jection to its use in privy vaults, cess-pools, etc., but would be an objection to its use in chamber vessels, the contents of which were to be thrown into water closets.

To test the keeping properties of a mixture of chloride of lime and sulphate of lime, mixed together in equal quantities, by weight, I exposed a layer having a thickness of about one and a half inches in a shallow vessel, and, for comparison, a mixture of equal parts of chloride of lime and sand in a similar vessel. At the outset of the experiment the available chlorine in each specimen was found, by Dr. Abbott, to be 15 per cent. At the end of a week the mixture with plaster contained 12.9 per cent. of available chlorine, and the mixture with sand 6.8 per cent. At the same time two fruit jars were filled about one-third full with the two mixtures, and the metal covers were screwed on. In these closed jars the mixture with sulphate of lime contained 13.5 per cent. of available chlorine at the end of two weeks, and the mixture with sand 11.8 per cent.

G. M. Sternberg.

THE COMPARATIVE ANTISEPTIC VALUE OF THE SALTS AND OXIDES OF MERCURY.

By George M. Sternberg.

In the introduction of this report the statement is made that "a complete investigation of both disinfectants and antiseptics being impracticable in the time and with the resources at command, the Committee decided upon so far departing from the letter of the resolutions of Dr. Hibberd as to limit its inquiry altogether to disinfectants, and to omit all investigations into the action of antiseptics."

The present article is the result of a departure from this rule which the writer has made with reference to the salts and oxides of mercury, because of the special interest which they have from a therapeutical point of view, and because of the important indications which seem to be furnished by their antiseptic power for restricting the development of pathogenic organisms in the alimentary

canal, as well as in masses of decomposing organic material which might serve as pabulum for disease germs external to the body.

With the assistance of Dr. Abbott, I have recently made a series of experiments, the results of which are given in the following table:

	Active.	Failed.
Biniodide of mercury	1 : 20,000	1 : 40,000
Bichloride "	1 : 15,000	1 : 20,000
Protiodide "	1 : 10.000	1 : 20,000
Yellow oxide "	1 : 1,000	1 : 2,000
Black oxide "	1 : 500	1 : 1,000
Calomel		1 : 100
Blue mass		1 : 100

In every case the antiseptic was carefully weighed and added to 100 cc. of beef-peptone solution, or of veal broth. A similar quantity of the culture-fluid was put up as a *temoin* without the addition of the antiseptic. As the oxides and iodides of mercury are insoluble in water, the bottle was repeatedly shaken in order to dissolve in the albuminous culture-fluid as much of the antiseptic as possible. An undissolved remnant could, however, be recognized at the bottom of the bottle after this repeated shaking. Two drops of broken-down beef-stock were added to each bottle to cause speedy putrefaction of the culture fluid in the absence of a sufficiently potent inhibition of the developing power of the bacteria of putrefaction. In every case in the comparative experiment the culture-fluid became clouded, and had a putrefactive odor at the end of twenty-four hours.

The first column in our table shows the proportion in which the culture-fluid was preserved from any appearance of decomposition for at least a week, the duration of the experiment. In the proportion given in the second column a decided inhibiting power was shown, except in the case of calomel and blue mass, which, in the proportion given (1 : 100), gave no evidence of antiseptic power. The other salts and oxides in the list prevented decomposition for twenty-four hours in the proportion given in the second column; and it was not until the

second day that the bacteria of putrefaction commenced to form a cloud at the upper surface of the fluid, which gradually extended until the fluid had entirely broken down, usually by the third or fourth day. The bottles containing the biniodide (1 : 20,000), and the bichloride (1 : 15,000) have now been standing in the laboratory for three weeks, and are as transparent and free from odor as the day they were put up. These results agree with those reported by Miquel.

So far as I know, the antiseptic value of the protiodide and of the oxides of mercury has not heretofore been determined. I shall refrain at present from making any remarks upon the therapeutic possibilities which these figures suggest, or upon the possible explanation of the *modus operandi* of the protiodide, given daily for many months in the cure of syphilis, or of the use of yellow oxide as a remedy for septic fermentation in the alimentary canal. The still greater inhibiting power of mercuric chloride for the spores of *B. anthracis* has already been referred to in the paper published on page 51 of this report.

SULPHUR DIOXIDE.

By George M. Sternberg.

Vallin, to whom we are indebted for the best practical "treatise upon disinfectants and disinfection"* which has yet been published, says: "Sulphurous acid, obtained by the combustion of sulphur in free air, occupies almost the first place among the veritable disinfectants." (*Op. cit.*, p. 243.)

This is the deliberate judgment of one who had carefully considered the experimental evidence accessible at the time this opinion was formulated (1882).

The use of sulphurous acid gas as a disinfecting agent

* E. Vallin. Médecin Principal de 1re Classe de l'Armée, Professeur d'Hygiéne a l'école de Méd. Militaire du Val-de-Grace, etc. Traité des Désinfectants et de la Désinfection, Paris, 1882.

has come down to us from remote antiquity, and it is safe to say that no gaseous disinfectant known is more extensively used, or has a higher place in the confidence of leading sanitary authorities at the present day. So well established is the belief that the fumes of burning sulphur will destroy the infection of small-pox, scarlet fever, yellow fever, etc., that it is probable that many believers in the germ theory of disease would be disposed to abandon this belief rather than to give up their faith in the disinfecting power of sulphurous acid gas, in case the experimental evidence relating to the germicide power of this agent should be in conflict with the results of their experience.

It is the object of the present paper to present the experimental evidence for the consideration of sanitarians, and, as the subject is one of great practical importance, the paper will necessarily be one of considerable length.

Before the modern methods of isolating and cultivating pathogenic micro-organisms had been perfected, various efforts had been made to determine by experiment the disinfecting power of sulphurous acid gas. One of the first of these experiments upon record is that which the Russian physicians are said to have made at the time of the pest in Moscow, in 1771. According to Dr. A. Wolff, ten cloaks (*pelisses*) which had been worn by soldiers seized with the plague, during their sickness, were exposed to fumigation (*une forte fumigation*) with sulphur and saltpetre. Ten criminals, condemned to death, were then required to wear these garments, and not one of them contracted the malady. In the absence of any control-experiment in which similar garments not disinfected were proved to communicate the disease, we cannot admit that disinfection was accomplished in this instance, as claimed by the Russian physicians, by the fumigation resorted to. The same criticism may be made with reference to most of the evidence relied upon at the present day, which is supposed to establish the value of the agent in question. It is negative in character, and we have no control-experiments. Moreover, accompanying or follow-

ing the fumigation, other measures are commonly adopted, such as free ventilation and cleansing of apartments, exposure of clothing and bedding to an abundance of fresh air, etc. As in clinical experiments a fictitious value is often assigned to remedies by reason of the failure of the experimenter to recognize the influence of the *vis medicatrix naturæ*, so there is reason to believe a "disinfectant" may often establish a temporary reputation, at least, upon the real virtues of an abundance of fresh air, together with a free use of hot water and scrubbing brushes, with perhaps a judicious use of the whitewash brush in addition. These remarks are made not to throw discredit in advance upon the agent under consideration, but with a view to showing that a careful survey of the experimental evidence is necessary, and that a spirit of scientific conservatism is required when the attempt is made to estimate the value of negative evidence in a case of this kind.

In vaccine virus we have an infectious material which seems especially well adapted as a test of disinfecting power, and the inference seems justified that an agent which will destroy the specific virulence of this material may also be relied upon for the destruction of the smallpox infection. The writer applied this test in a series of experiments made in 1880 and 1881, and published in the *Bulletin* of the National Board of Health. The results obtained have been summarized by Vallin, and, as his work is before me, I quote from it as follows:

"Dougal and Baxter have shown the neutralizing power of sulphurous acid upon different kinds of inoculable virus. Both exposed for ten minutes, in an atmosphere saturated with sulphurous fumes, ivory points charged with dry vaccine virus. At the end of this time the neutralized virus was inoculated by three punctures in the arm of a non-vaccinated infant; while in the other arm, at the same time, three punctures were made with ivory points charged with the same virus, but not exposed to sulphurous acid. The last-mentioned punctures were all followed by perfectly developed vesicles, the punctures upon the other arm gave no result. Unfortunately the quantity of the acid, or of sulphur burned, is not men-

tioned ; this time, by exception, Baxter leaves us in doubt.

"Dr. Sternberg, surgeon in the United States Army, has taken up these experiments in an ingenious manner and with greater precision. This author burned a determined quantity of sulphur in a wooden box having a capacity of ten litres. He submitted to the vapors thus produced liquid vaccine virus, placed in a watch-glass, for a period of twelve hours. The following day unvaccinated infants were inoculated in one arm with the disinfected virus, and in the other with a portion of the same virus not exposed to the disinfectant.

"Liquid virus thus exposed for twelve hours to the action of the fumes from 3 centigrammes of sulphur burned in the air-chamber—that is, 24 cubic centimetres of gas to 10 litres of air, or a little more than two parts in a thousand—produced but a single vesicle, while the non-disinfected virus in the other arm gave a successful result in every instance. Upon doubling the amount of sulphur —that is, 6 centigrammes to 10 litres, or 6 grammes per cubic metre, or 5 volumes of sulphurous acid to 1,000 volumes of air—and reducing the time of exposure to four hours, the vaccine still remained inactive after exposure.

"It suffices, then, to burn 5 grammes of sulphur in a cubic metre of air, in order to neutralize *liquid* vaccine, but this vaccine coagulates almost immediately upon contact with sulphurous acid gas ; and this contributes, perhaps, to destroy, or to modify, its inoculability. We shall see, further on, that experiment made in spaces of such small dimensions may lead to grave errors.

"In order to disinfect dry vaccine, Sternberg found that a considerably larger quantity of sulphur was required, viz., 16 grammes per cubic metre, which corresponds with the classical proportion of one volume of sulphurous acid gas to 100 volumes of air ; in this regard the experiments of Sternberg confirm those which have been obtained by many other authors."

Baxter has also tested the power of an aqueous solution of sulphur dioxide to disinfect the virus of glanders, and an infectious form of septicæmia—induced—in guinea-pigs. Four parts of SO_2 by weight, added to 1,000 parts of the diluted virus of glanders, neutralized its infective properties, as determined by inoculation experiments. The septic virus was destroyed by 3 parts by weight in 100, while 6 in 1,000 failed. The time of exposure to the disinfectant in these experiments is said to have been from

thirty minutes to three hours; but this is considered by Baxter to be a matter of secondary importance, and, according to him, disinfection is complete at the end of five minutes, when the virus has been intimately mixed with the disinfecting solution.

The wide limits (3 : 100 and 6 : 1,000) between success and failure in these experiments of Baxter, and an evident want of precision in the conditions, especially as to time, induced Vallin, from whom we have quoted the above results, to undertake additional experiments with the virus of glanders: He says:

"I had, in January, 1881, an opportunity to repeat these experiments. A patient in the service of our colleague, M. Gaujat, at Val de Grace, was attacked with glanders —*abces farcineux multiples*—and furnished an inoculable pus, with which Dr. Kiener produced in several animals, guinea-pigs, cats, etc., the characteristic lesions of glanders. A small quantity of this pus, obtained directly from the patient, and placed in a watch-glass, was exposed for twelve hours in a wooden box having a capacity of exactly 100 litres. Two grammes of sulphur were burned in this box, an amount which corresponds with 20 grammes per cubic metre. The following day a guinea-pig was inoculated with the disinfected virus. At the end of three months this animal remained in perfect health. Another guinea-pig, inoculated the same day with a second portion of the same virus preserved between two watch-glasses, and not disinfected, died at the end of two months with the characteristic lesions of glanders."

Additional experiments were made with the same virulent pus dried in the open air upon little squares of flannel. Inoculation with this material failed after exposure to sulphur dioxide generated by burning sulphur in the proportion of 15 grammes per cubic metre. But inoculation with the desiccated virus not exposed to a disinfecting agent also failed, and Vallin remarks that desiccation alone had perhaps sufficed to destroy the virus, as in the experiments of Galtier. Experiments were also made with pus obtained from a tuberculous abscess in a case of Pott's disease. This material was divided into two portions and placed in watch-glasses. One portion was subjected for twelve hours to the action of sulphur

dioxide generated by burning sulphur in the proportion of 20 grammes per cubic metre. This pus, injected subcutaneously into a guinea-pig, produced no result. At the end of four months the animal remained in good health. The non-disinfected pus injected into another guinea-pig caused its death on the forty-eighth day. Its liver, spleen, lungs, and peritoneum, were filled with tubercle granules. Other experiments were made with pus obtained from two chancres "of doubtful nature." Inoculation with this material, after exposure to SO_2 (15 grammes of sulphur per cubic metre of space), gave no result, while the non-disinfected pus produced "characteristic pustules."

In the experiments thus far recorded the disinfecting power of the agent under consideration is fully established for certain kinds of material, and especially for vaccine virus. In my own experiments upon this material the results were extremely definite, and the conditions observed were such as to render them unimpeachable. Experiments upon original virus from various sources are especially valuable from a practical point of view, inasmuch as the results obtained are evidently reliable guides with reference to the destruction of infective virulence in the several kinds of material experimented upon, and this without regard to any theory as to the nature of the morbific agent. We know, however, that in several infectious diseases, at least, this agent is a living organism or germ. It is, therefore, a matter of importance to determine the exact germicide power of this and other agents which have been proved to be useful disinfectants, and numerous experiments have been made with this object in view. If the germ theory of disease is correct, as applied to all infectious diseases, there should be a correspondence between the results obtained in experiments with original virus and those made upon pure cultures of the pathogenic organism to which such virus owes its infecting power. This is an interesting question in connection with the agent under consideration, inasmuch as Wernitz has shown that sulphurous acid

promptly neutralizes the action of non-living ferments in comparatively small amounts, and there is therefore ground for the supposition that the specific disease-poisons destroyed by this agent in the disinfection experiments above recorded were of this nature.

According to Wernitz,* the action of pepsine, of ptyaline, of invertine, and of diastase, is prevented by the presence of an aqueous solution of SO_2 of 1 : 1,317 to 1 : 8,600 (by weight); while the action of myrosine and of emulsine is neutralized by 1 : 21,000.

Wernich, of Breslau, experimenting in the Pathological Institute of Berlin, 1877, saturated strips of woolen or cotton goods with putrid liquids, and exposed them under a bell-jar containing a definite proportion of sulphurous acid gas. Then, with proper precautions, these strips were introduced into tubes containing Pasteur's culture solution, thoroughly sterilized. The development of bacteria in this fluid was taken as evidence that disinfection was not complete. The results obtained are summarized by Vallin† as follows :

When the strips of material were suspended for several hours under a bell-jar containing 3.3 volumes of sulphurous acid per 100 volumes of air, they were not disinfected. When the proportion of gas was increased to 7 per cent., or even to 4 per cent., the time of exposure being six hours, the strips of goods no longer fertilized culture liquids.

Schotte and Gärtner,‡ in 1880, experimented also upon the bacteria of putrefaction. In a chamber having a capacity of 40 cubic metres they placed, at various levels, shallow dishes containing culture-liquids, into which putrefactive bacteria were introduced. Sulphur was burned in earthen vessels, placed about four feet above the level of the floor. When the amount burned was in the proportion of 15 grammes per cubic metre of space—an amount which gives one volume of SO_2 to 100 volumes of

* I. Wernitz, Ueber die Wirkung der Antiseptica auf ungeformte Fermente, Dorpat, 1881.

† Op. cit., p. 254.

‡ Viertelj. f. Oeff. Gesund., 1880, t. xii. pp. 337—376.

air—it was found that, at the end of six hours, the gas had escaped to such an extent that it was possible to enter and remain in the room, although during the entire time the doors and windows had been carefully closed. The result of the experiment was that the culture liquids exposed in the upper part of the chamber remained clear, while those placed upon the floor broke down at the end of twenty-four to thirty-six hours. When the amount of sulphur burned was increased to 28 grammes per cubic metre (about two volumes per cent. of SO_2), disinfection was complete. When the culture fluids were placed upon the shelves of a cupboard, "half-closed," and situated in the corner of the chamber, disinfection was only obtained by burning 92 grammes of sulphur per cubic metre of space.

We remark that the test of disinfection was not satisfactory in these experiments. A certain amount of SO_2 was, no doubt, absorbed by the exposed culture liquids, and these, in successful experiments, failed to break down, because of the antiseptic or restraining influence of this agent. But, to prove that the germs of putrefaction in these culture liquids were killed, it would have been necessary to inoculate fresh cultures with a small amount of this material which had been exposed to the action of a disinfectant.

Other experiments were made by the authors named, which we shall quote in the language of Vallin :*

"Strips of very thick woolen goods were soaked in culture liquids containing bacteria. These were dried, a proceeding which did not destroy the vitality of the bacteria, as proved by culture experiments. These strips were suspended from a cord stretched across the middle of the chamber at a level of about five feet above the floor. Half of the strips were left dry ; the other half, after having been dried, were again moistened, so that they might be exposed in a moist condition to the sulphurous vapors. Our authors arrived at the following unexpected results : Even after having been exposed to the action of sulphur dioxide, produced by the combustion of 92 grammes of sulphur per cubic metre, the moist-

* Op. cit., p. 253.

ened strips caused culture liquids, in which they were placed, to break down at the end of three or four days. The dry strips exposed in the same way produced the same results somewhat sooner—*dans le 3e jour*. Gärtner and Schotte have concluded from this that the germs, or proto-organisms, hidden in the deeper portions of the very thick woolen goods, resist strong fumigations with sulphurous acid gas, or, with other disinfectants. They arrive almost to the point of doubting the possibility of a certain and absolute disinfection, at least by the gases or vapors."

The limits of this paper admit only of a brief abstract of the elaborate experimental researches relating to the value of sulphur dioxide as a disinfectant, made by Koch * and by Wolffhügel,† under the auspices of the Imperial Board of Health of Germany, and published in the first volume of the *Mittheilungen aus dem Kaiserlichen Gesundheitsamte*.

The experiments of Wolffhügel relate to questions concerning the practical use of SO_2, the best methods of producing it, etc., while those of Koch are designed to fix its exact germicide value. In Koch's first experiments sulphur dioxide was generated by burning sulphur in a box having a capacity of 290 litres. Other experiments were made in a closed chamber. The amount of SO_2 present was estimated at the outset and at various intervals. Thus in his third experiment, in which the disinfection box was used, the amount of SO_2 was :

At first,	6.13	vol. per cent.
At the end of 24 hours,	4.88	" "
At the end of 72 hours,	4.47	" "
At the end of 96 hours,	3.3	" "

In this experiment only spore-containing material was exposed in the disinfection box. This consisted of old dried milzbrand (anthrax) blood, anthrax spores dried upon silk threads, spore-containing earth, and hay bacillus spores dried upon blotting paper. The result was entirely negative, the developing power of the spores was

* Op. cit., pp. 252-261.

† Ibid., pp. 188—233.

not in any instance destroyed, even after ninety-six hours' exposure, and a mouse inoculated with the dried blood, exposed for this length of time, died promptly of anthrax.

The results obtained with material not containing spores, were more satisfactory ; but still not of a nature to give confidence in this agent as a reliable disinfectant for the purposes and in the manner in which it is commonly applied. The experiments show in the first place, that it is not safe to apply the data obtained by burning sulphur under a bell-jar, or in a tight box of small dimensions, to disinfection on a large scale, owing principally to the rapid loss of the gas which occurs in an ordinary apartment, with all apertures carefully closed. Thus in Koch's fifth experiment in a closed chamber, the rapid loss of SO_2 is shown by the following figures :

At the end of half an hour, 3.12 vol. per cent.
At the end of 2 hours, 1.25 " "
At the end of 22 hours, 0.015 " "

In Experiment No. 2, made in a box having a capacity of 290 litres, anthrax bacilli, without spores, from the spleen of a mouse recently dead, and dried upon silk thread, were destroyed by exposure for thirty minutes to SO_2 in the proportion of 1 vol. per cent.

In Experiment No. 7, also made in the box, the amount of SO_2 at the outset was 0.84 ; at the end of twenty-four hours, 0.55. An exposure of one hour in this experiment destroyed anthrax bacilli (still moist) upon silk thread. Four hours' exposure failed to destroy the vitality of *Micrococcus prodigiosus* growing upon potato, but twenty-four hours' exposure was successful. The same result was obtained with the bacteria of blue pus.

In Experiment No. 8, it was found that an aqueous solution of SO_2 of 11.436 per cent., by weight, did not destroy anthrax spores in twenty-four hours, but was successful in forty-eight hours. When the proportion of SO_2 was reduced to 5.718 per cent. disinfection was only accomplished after five days' immersion in the aqueous solution.

According to Arloing, Cornevin, and Thomas, sulphurous acid does not destroy the bacteria of symptomatic anthrax, which contain spores.

The experimental results thus far recorded will perhaps prepare those who have heretofore had implicit faith in the disinfecting power of sulphurous acid, to accept without too much incredulity the following results obtained by the writer in recent experiments with this agent.

At the request of Dr. Wm. M. Smith, Health Officer of the Port of New York, I visited that city on the 9th of January, 1885, for the purpose of applying biological tests in an experiment designed to ascertain whether it is practicable to disinfect rags in the bale. A manufacturing chemist of New York proposed to accomplish this by injecting sulphur dioxide into the interior of the bales through hollow tubes. The SO_2 had been compressed to the liquid form in copper cylinders, and being under a pressure of six atmospheres was expected to permeate the bale thoroughly when the valve was opened leading to the hollow and perforated screws introduced into it. The bale was to be placed in a closed chest of moderate dimensions, and disinfection was to be accomplished within a few minutes.

The experiment was made at the Baltic Stores, Brooklyn, in the presence of Dr. Smith, Health Officer of New York, Dr. Raymond, Commissioner of Health of the City of Brooklyn, and several other gentlemen belonging to the Health Department of New York and of Massachusetts.

The following material which I had brought in sterilized tubes from the biological laboratory of Johns Hopkins University, Baltimore, was introduced into the bale through openings made with a pocket-knife. The depth of these openings was from two to four inches. The material to be disinfected was upon pledgets of cotton previously sterilized, which had been saturated with pure cultures of the various test-organisms. Some of these pledgets had been subsequently dried at low temperatures, others remained

moist. The apertures in the bale were closed, after introducing these bits of cotton, by tamping in strips of old muslin. When these preparations had been made the bale of rags was placed in the disinfection chamber and the gas turned on. The time during which the gas was allowed to flow was three minutes and a half. The pressure, as shown by a gauge in connection with the copper cylinder, was eighty pounds at the commencement and seventy-five at the close of the experiment. The disinfection chamber was not tight, and all those in the vicinity were obliged to retire to a respectful distance to windward while the gas was flowing and for a considerable time afterward, owing to the abundant escape and stifling effect of the SO_2. It was only after an interval of twenty or thirty minutes that the disinfection chamber could be approached to withdraw the bale, and after it had remained in the open air for some time, I was almost suffocated while removing the pledgets of cotton containing the test organisms. These were at once placed, with sterilized forceps, in sterilized glass tubes, and each tube was at once plugged with sterilized cotton. In this way they were taken back to the laboratory in Baltimore, where the test of disinfection was completed by culture and inoculation experiments. The nature of the material and the results of the experiment are given in the table on page 80.

Other pledgets of cotton had been exposed in the bale, which had been saturated with tuberculous sputum, but this part of the experiment was not followed up, owing to the scarcity of rabbits for inoculation.

Soon after my return to Baltimore, I received from the manufacturer in New York, a copper cylinder, containing a liberal supply of SO_2 in liquid form. With this the following experiment was made, January 25, in a closet having a capacity of eight cubic yards. This closet, in the basement of the biological laboratory, had been constructed under the stairway as a refrigerating chamber. The walls were double and filled in with asbestos, and the door, made in the same way, was fitted to close as accurately as possible, and held closed by a strong clamp.

Number of tube containing cotton pledget.	Nature of material.	Test by cultivation.	Result.	Test by inoculation.	Result.
No. 1.	*Bacillus anthracis* containing spores (dry).	One culture tube.	Abundant development of anthrax filaments in twenty-four hours.	One rabbit inoculated subcutaneously.	Died of anthrax on third day.
No. 2.	*Bacillus anthracis* containing spores (dry).	One culture tube.	Abundant development of anthrax filaments in twenty-four hours.	One rabbit inoculated subcutaneously.	Died of anthrax on third day.
No. 3.	*Bacillus anthracis* containing spores (moist).	Two culture tubes.	Abundant development in both.	One rabbit inoculated.	Survived the inoculation.
No. 4.	*Bacillus subtilis* spores (dry).	Two culture tubes.	Abundant development of *Bacillus subtilis* in both.		
No. 5.	*Bacillus subtilis* spores (moist).	Three culture tubes.	Abundant development of *Bacillus subtilis* in each.		

A sufficient quantity of the liquid SO_2 to produce ten volumes per cent., when volatilized in the closet described, was drawn from the copper cylinder into a large beaker, quickly placed upon the floor of the disinfection chamber, and the door closed. At the end of twelve hours the door was thrown open and the gas permitted to escape. The test-organisms were exposed upon little pledgets of absorbent cotton, which had been saturated with culture-fluids, containing the various micro-organisms employed. Some of these pledgets of cotton had been dried at a low temperature in advance of the experiment, and others were exposed moist.

Some of the prepared bits of absorbent cotton were placed in glass tubes, open at one end and sealed at the other. Other pledgets were loosely folded in a single thickness of heavy muslin which had been sterilized by heat. The ends of these little packages were left open, so that the SO_2 might have free access to the interior. These packages properly labeled, were placed in the inside pockets of a coat, and this was suspended in the closed chamber used for the experiment. The glass tubes were placed in an open pasteboard box upon the floor of the disinfection chamber. Other pledgets of cotton, similarly prepared, were wrapped up in little bundles of cotton, weighing half an ounce each, and enveloped in a single layer of sterilized muslin. Still other pledgets were wrapped up in a woolen blanket, in such manner that they were in the centre of a compact bundle, eighteen inches long, and ten inches in diameter. The result as determined by cultivation experiments, was as follows :

Cotton pledgets exposed in glass tubes.

Micrococci from case of vaccinal erysipelas, moist, and dry. No development from the moist material, abundant development of micrococci from dry material.

Bacillus subtilis (spores), moist and dry. Abundant development of *B. subtilis* at end of twenty-four hours from both moist and dry material.

Bacillus anthracis (spores), dry. Abundant development of anthrax bacilli within twenty-four hours.

Cotton pledgets placed in coat pocket.

Micrococci from case of vaccinal erysipelas, moist and dry. Two culture-tubes inoculated from each. Abundant development of same micrococci within twenty-four hours.

Bacillus anthracis (spores), moist and dry. Two tubes inoculated from each. Pure cultures of *B. anthracis* obtained in each within twenty-four hours.

Bacillus subtilis (spores), moist and dry. Two tubes inoculated from each. At the end of twenty-four hours a mycoderma of *B. subtilis* was found upon the surface of the culture liquid in each of these tubes.

The complete failure thus far made it useless to open the bundles of cotton and the rolled blanket, which were put aside for further experiments.

On the 1st of February a second experiment was made in the same disinfection chamber upon test-organisms prepared as before. In this experiment the conditions were changed by the introduction of steam into the chamber through a tube connected with a retort outside. Two litres of water were evaporated, and the steam passed into the chamber during the first four hours of the experiment. The amount of SO_2 in this experiment was increased to twenty volumes per cent.; the time of exposure was twelve hours; the result as follows:

Organisms exposed in coat-pocket.

Coat suspended from wall, and pledgets of cotton loosely folded in filter paper, with ends of packages open for free admission of gas.

B. subtilis (spores), moist and dry. Abundant development in twenty-four hours in culture fluids inoculated with the exposed spores.

B. anthracis (spores), moist and dry. Abundant development of anthrax filaments in culture-tubes inoculated with this material.

Micrococci—pure culture—from blood drawn from inflamed area in a case of erysipelas. Two dry and one moist pledget. Pure culture of this micrococcus were

obtained from all of these after exposure in coat-pocket as described.

Organisms exposed on pledgets of cotton in open tubes placed upon the floor of disinfection chamber.

B. subtilis (spores), dry and moist. Abundant development in culture fluids.

B. anthracis (spores), dry and moist. Pure cultures obtained from exposed material.

Micrococci, from erysipelas (same stock as above), two pledgets, dry. Pure cultures obtained from both.

The complete failure to destroy the test-organisms under the conditions mentioned induced me to try the following experiment:

February 2.—Pure SO_2 in liquid form was poured into a tube (experiment in duplicate) containing spores of *B. subtilis* on dry cotton. The rapid volatilization of the liquid, produced, of course, intense cold. As the tube was long and narrow, and volatilization was restrained by the low temperature, the time of contact with the SO_2 was at least ten minutes. The vitality of the spores thus brought in contact with the liquid SO_2 was not impaired, as shown by culture experiments.

The experiment was repeated Feb. 5, with anthrax spores upon *moist cotton*. The result was the same. Anthrax filaments appeared in cultures inoculated with these spores at the end of forty-eight hours.

It was evidently useless to extend these experiments so far as spores are concerned; but the question remained as to the practicability of destroying pathogenic micrococci and bacilli without spores. As Koch has shown that the loss of sulphur dioxide is very rapid from a room which is carefully closed to prevent its escape, the following experiments were made in a gas-tight receptacle:

February 2.—The following named test-organisms were placed under a bell-jar, having a capacity of one gallon. The jar was sealed below by resting in a trough containing mercury. Enough liquid SO_2 to make twenty volumes per cent. was introduced into this jar, and was, of

course, quickly volatilized. The time of exposure was eighteen hours ; results as follows :

Micrococci (pure culture) obtained from a case of vaccinal erysipelas (culture started from drop of blood drawn from inflamed area). One moist and two dry pledgets of sterilized cotton, previously saturated with this culture, were exposed in glass tubes open at one end. Also a few drops of the culture-fluid poured into a similar tube. Result negative ; disinfection was complete, as proved by attempt to start cultures from the exposed organisms.

Micrococci (pure culture) from blood of woman with puerperal septicæmia (fatal case). Exposed one pledget of cotton, moist, in glass tube ; and a few drops of culture-fluid in the bottom of two other glass tubes; disinfection complete.

Micrococci (pure culture) from vaccine vesicle. Exposed two pledgets of cotton, moist, and one tube containing a few drops of pure culture ; disinfection complete.

Micrococcus ureæ (pure culture in beef tea). Exposed one pledget of cotton, moist, and one tube containing a few drops of culture ; disinfection complete.

Having determined by this experiment that SO_2, even in the absence of moisture, may kill microccocci, a second experiment was made to ascertain whether the quantity of the disinfecting agent could be reduced, so as to bring it more nearly within practical limits.

Feb. 7.—SO_2 was introduced under the bell-jar, as above described, and the following test-organisms exposed to its action for twenty hours :

Micrococci from vaccinal erysipelas.* Exposed two pledgets of cotton, dry, in glass tubes. From one of these, cultures of this micrococcus were obtained ; cultures inoculated from the other remained sterile. Two pledgets of cotton moistened with a recent culture were

*The writer does not commit himself to the view that the micrococci from the various sources mentioned are specifically different. and the cause of the morbid phenomena in the individuals from whose blood the cultures were started ; inasmuch as he has not been able to obtain any definite proof that such is the case. On the other hand he admits that it is extremely probable that they are concerned in the development of these morbid phenomena, and are in fact pathogenic organisms.

also exposed. Cultures from these remained sterile. A few drops of a fresh culture placed in the bottom of a glass tube subsequently fertilized sterilized culture-fluids —failed to disinfect.

M. ureæ, exposed upon two pledgets of cotton, moist ; disinfection complete.

In the above experiment the material to be disinfected, was placed near the bottom of the jar. In the following experiment a taller jar, having a capacity of five litres, was used; and the test organisms were exposed upon a shelf near the centre of the jar. As before, liquid SO_2 was introduced in an open beaker, in a proper quantity to make four volumes per cent. The time of exposure was twenty-four hours.

Micrococci (pure culture) from vaccine vesicle, on cotton, moist ; disinfection complete.

Micrococci, puerperal septicæmia, pure culture on cotton, moist ; disinfection complete.

Micrococci, vaccinal erysipelas, pure culture on cotton, moist ; failure to disinfect.

Micrococci, from vaccine vesicle, on cotton, dry, in duplicate ; disinfection complete in one, failure in the other.

I have also tested the germicide power of an aqueous solution of SO_2 on the above-mentioned micrococci, with the following results :

February 5.—Equal parts of a recent culture of micrococci from vaccine vesicle, micrococci from case of puerperal septicæmia, and *M. ureæ*, were added to a standard solution of SO_2 containing five per cent. by weight. The time of contact was two hours, after which two culture tubes were inoculated from each ; no development occurred—disinfection complete.

7th.—The standard solution of SO_2 (five per cent.) diluted to 1 : 50 was added, in equal portions, to a pure culture of the micrococcus from vaccinal erysipelas (making the dilution 1 : 100=0.05 per cent. of SO_2 by weight, or 1 : 2,000). Cultures inoculated after two hours' contact remained sterile. At the same time a solution of 1 : 100

was added to a culture of the micrococcus from a vaccine vesicle (*i. e.*, 1 : 4,000 by weight); in this case disinfection failed.

10*th.*—The above experiment was repeated with the last-mentioned micrococcus with solutions containing 1 : 1,000, 1 : 2,000, and 1 : 4,000, of SO_2 by weight (after admixture with the culture fluid).

The result corresponded with that previously obtained. Disinfection was accomplished by the solution of 1 : 1,000 and 1 : 2,000 ; but failed when the amount was reduced to 1 : 4,000.

11*th.*—The same result was obtained with a recent culture of the micrococcus from case of puerperal septicæmia—*i. e.*, the standard solution of five per cent., when diluted with forty-nine parts (1 : 50) of distilled water, in two hours' time destroyed the developing power of this micrococcus, while the same solution diluted to 1 : 100 (1 : 4,000 of SO_2 by weight) failed to disinfect.

These results correspond with those reported by Jalan de la Croix, who found that one grain of SO_2 in 2,000 of bouillon filled with growing bacteria, causes development to cease, and destroys the vitality of these bacteria. When spores were present, however, it was necessary to increase the amount to 1 : 135 (in how long a time ?).

I may add, as a matter of interest, although not directly relating to our present object, that the same standard solution of five per cent. by weight, when added to culture-fluids in the proportion of 1 : 250 (=1 : 5,000 of SO_2 by weight) prevents the development of all the above-mentioned micrococci ; while 1 : 500 (1 : 10,000 of SO_2) fails to prevent the development of the bacteria of putrefaction, or of the micrococcus from a vaccine vesicle, upon which organisms alone I have thus far tested the antiseptic power of this agent. These results also correspond closely with those of de la Croix, and show that sulphur dioxide ranks very high as an antiseptic.

In view of the experimental data recorded it is evident that the use of sulphur dioxide for the disinfection of spore-containing material must be abandoned. This is

the conclusion of Wolffhügel* on the basis of Koch's biological tests, and his own experiments. He is therefore inclined to abandon entirely the use of this agent for disinfecting purposes. He says, with reference to the question of its use for material not containing spores, that the answer to this question has very little interest, from a practical point of view, as it is impossible to say in the present state of knowledge whether we have to deal with material free from spores or otherwise. Under the circumstances Wolffhügel thinks that we will do well to abandon sulphur dioxide, and to use only such methods of disinfection as will be effective without reference to the presence or absence of spores.

I am not ready to go to this length, and to recommend the abandonment of an agent which enjoys the confidence of practical sanitarians for the destruction of the infection of small-pox, of scarlet fever, of diphtheria, of cholera, and of yellow fever, upon the ground that it fails to destroy the spores of the anthrax bacillus, or of *B. subtilis*. For the truth of the germ theory has not yet been definitely established for any one of the diseases named, and Wernitz has shown the power of this agent to neutralize non-living ferments. Admitting, however, as I do, the great probability that the infectious agent in these diseases is a living germ, we have good reason for believing that spores are not formed in any one of these diseases. We must not then be too exacting with reference to this agent, until we are able to recommend something better in its place for the purposes to which it is commonly applied, viz., for the disinfection of apartments and ships.

My experiments show most conclusively that it does destroy the specific infecting power of vaccine virus dried upon ivory points, when present in the air of a disinfecting chamber in the proportion of one volume per cent., and that in aqueous solution it destroys the vitality of various micrococci in comparatively small amounts. It is even practicable to destroy these organisms dried upon

* Op. cit., vol. i. p. 232.

pledgets of cotton by long exposure in gas-tight receptacles. But the conditions of success are such that it appears almost impracticable to conform with them in practice on a large scale, and it is evident that much of the so-called "disinfection" with this agent is a farce.

I am convinced that the percentage of SO_2 present in the disinfection chamber, above a certain limit, is of less moment than certain conditions relating to the material to be disinfected. Thus Koch succeeded in destroying the vitality of anthrax bacilli, still moist from the spleen of a mouse, and attached to silk threads, by exposure for one hour to 0.48 volume per cent. of SO_2, in a disinfection chamber the atmosphere of which was loaded with moisture. In my own experiments with vaccine virus upon ivory points a still smaller amount (5 volumes per 1,000) was effective in four hours time. Here the favorable conditions are without doubt the very thin stratum of material to be disinfected, and the fact that it is thoroughly moistened.

Admitting that, in the absence of spores, micro-organisms suspended in the atmosphere, or attached to the surface of objects may be destroyed by sulphur dioxide, when generated in a sufficient quantity in a well-closed apartment, and in the presence of moisture, the question remains whether the same object may not be as well accomplished by thorough ventilation, and by washing all surfaces—walls, ceilings, floors, furniture. etc., with a 1 : 1,000 solution of mercuric chloride, which we know to be promptly destructive of germs of all kinds.

EXPERIMENTS WITH SULPHUROUS ACID GAS.

By J. H. Raymond.

The following experiment was made in Brooklyn, at the request of the Commissioner of Health, with the object of determining the germicide value of sulphurous acid gas, produced by the burning of sulphur in the manner

recommended by boards of health generally. Dr. George M. Sternberg, U. S. A., kindly proffered his services, and conducted the inoculation with the material prepared by him at John Hopkins University. The methods employed were the same as he has employed in similar experiments, and which he has repeatedly described. Dr. W. E. Griffiths, of Brooklyn, and the reporter, assisted in the experiment.

The room selected was on the second floor of a private residence, and connected with it was a small clothes closet. Two doors opened out from it, one into the hall; the other into an adjoining room. The experimental room had a single window. All cracks and crevices, by which fumes could escape were carefully closed by cotton. In the room were the following articles: A carpet on the floor; a wooden bedstead with springs, on which were two mattresses in close contact; a chair, over which was spread a bed-quilt; a sofa; an empty stand of drawers, on the top of which was placed a large book; the closet was empty. The room and closet together contained, as nearly as could be ascertained, 1850 cubic feet of air space, and were in free communication.

On the 18th of April, pieces of blanket, about four inches square, soaked with blood from a rabbit, killed while affected with septicæmia, and other similar pieces soaked with blood from another rabbit affected with anthrax, were exposed in different parts of the room, as hereafter described. Some of these pieces were folded double, with the blood inside the fold; others were left unfolded.

Piece No. 1, soaked with septicæmic blood, unfolded, was placed on the floor of the closet.

No. 2, septicæmic blood, unfolded, was pinned to the upper part of the window frame, eight feet from the floor.

No. 3, septicæmic blood, folded, was attached to frame of closet door, seven feet from floor.

No. 4, septicæmic blood, unfolded, was placed between the mattresses, which were in close contact.

No. 5, septicæmic blood, unfolded, pinned to the underside of the bed-quilt, which was spread over the chair.

No. 6, anthrax blood, unfolded, placed on the closet floor.

No. 7, anthrax blood, folded, attached to frame of closet door, seven feet from the floor.

No. 8, anthrax blood, unfolded, placed between the lower mattress and springs.

No. 9, anthrax blood, unfolded, attached to frame of the door leading into the adjoining room, six feet from the floor.

No. 10, anthrax blood, unfolded, placed between the mattresses.

No. 11, anthrax blood, unfolded, placed under the carpet, eight inches from the edge : the carpet again laid down, but not tacked.

No. 12, anthrax blood, unfolded, placed in the middle of the book, between the leaves, the book being closed.

No. 13 was a piece of blanket soaked with anthrax blood, which was not exposed in the room, but was prepared for purposes of comparison.

No. 14 was another piece soaked with septicæmic blood, and also not exposed.

Two half-quills of fresh bovine vaccine virus were placed on the stand of drawers, and one half-quill on the top of the frame of the door leading into the adjoining room. The corresponding halves similarly marked were placed in a tight preserve-jar, which was at once put in a refrigerator in another part of the house.

In the middle of the room was placed a large coal-scuttle, nearly filled with wet ashes, and in this an iron pot, holding four pounds of broken sulphur and two pounds of flowers of sulphur ; this was then well moistened with alcohol, and a lighted match applied. When the sulphur was well burning the door of the room was closed, which was at 1.25 P. M. At 11.25 P. M. the hall door and window were opened for one hour, and the room thoroughly aired. At the end of this time the odor of sulphur was distinctly perceived, but there was no difficulty of breathing in any

part of the room. The sulphur in the pot was completely consumed. At the end of the hour the door and window were again closed, and kept so until 10 A. M. the following day, the 19th. When the door was again opened the air of the room was so impregnated with sulphur that respiration was impossible, and an airing of ten minutes was necessary before it could be entered.

At the end of this time the pieces of blanket were collected, and at 12 M. healthy rabbits were inoculated by Dr. Sternberg with the blood soaked out from the pieces of blanket in sterilized beef-tea. The rabbits, as fast as inoculated, were put in a cage, each in a separate compartment, and given the same numbers as those of the pieces of blanket with the blood of which they had been inoculated. The inoculation was complete within an hour.

The vaccine which had been exposed to the fumes was put into the jar containing the non-fumigated virus, and the jar replaced in the refrigerator, where it was kept until the material was used in vaccination.

Results.

Rabbit No. 3, inoculated with septicæmic blood from folded piece which had been fumigated, was found dead in the cage at 7 A. M., April 21st, forty-three hours after inoculation. He was apparently well the night before; the exact time of death is not known.

Rabbit No. 14, inoculated with non-fumigated septicæmic blood, died at 2 P. M., April 21st, fifty hours after inoculation.

Rabbit No. 7, inoculated with anthrax blood from folded piece which had been fumigated, was found dead at 7 A. M., April 23d, ninety-one hours after inoculation, being apparently well the night before.

April 20th, a child, 7 months old, previously unvaccinated, was vaccinated by Dr. Griffiths in two places upon the same arm, one with virus from the fumigated half, and the other with virus from the non-fumigated half of the same quill. The latter was successful; the former failed utterly.

The same was practised upon a young lady, 20 years of age, showing no vaccine cicatrix, and stating that she had never been vaccinated, with a fumigated and a non-fumigated half of a quill with the same result, namely, failure from the fumigated and success from the non-fumigated slip.

A calf was vaccinated in the same way on the inner sides of the two thighs with the same result.

Interpretation of Results.—There seems to be no doubt that sulphurous acid gas, produced from burning sulphur, destroys the vitality of vaccine virus. This has been heretofore demonstrated by Dr. Sternberg, and this experiment confirms it.

It will be noticed that the rabbit inoculated with non-fumigated septicæmic blood, No. 14, died, as did also No. 3, the one inoculated from the folded piece of blanket, while all the other rabbits inoculated with septicæmic blood, were apparently unaffected and survived—even No. 4, which was inoculated with blood from the blanket placed between the two mattresses in close contact. I cannot understand how the gas could more readily have found its way between the mattress, and destroyed the germs there placed, than between the folds of a small piece of blanket hung up in the room.

As the rabbit inoculated with non-fumigated anthrax was apparently unaffected, while one inoculated with fumigated anthrax died, I think no conclusions of any value can be drawn from this part of the experiment.

Finally, after a careful review of the experiments and its results, I am led to regard the vaccine experiment as a success, and confirming what has already been well settled,—the experiment with septicæmia as unsatisfactory, and the one with anthrax as a failure.

As a matter of precaution, the rabbits were kept for one month after inoculation, at the end of which time all were well, save the three already referred to.

Note.—The experiment with the septic virus seems to me to have been quite satisfactory and definite. The *temoin* died at the proper time, showing the potency of

the virus. This potency was destroyed by the action of the sulphur dioxide in every case except in that in which the piece of blanket was folded, while the septic blood was still moist. This was the most difficult test as the layer of dried blood to be penetrated was twice as thick as in the unfolded pieces of blanket, and it was necessary that the gas should penetrate an entire thickness of blanket saturated with dried blood in order to reach the germs included in the material on the inside which cemented the folds of blanket together. The failure of the *temoin* in the anthrax experiment is a sufficient reason for excluding this part of the experiment. This failure was no doubt due to the fact that my anthrax stock is very much "attenuated" in virulence by having been cultivated in fluid media through many successive generations, and exposed often for weeks to the action of oxygen in the hermetically sealed flasks in which I keep my pure cultures. I have found that this same stock fails completely to kill white rats, but it commonly kills rabbits. Possibly the *temoin* in this experiment did not receive as large an amount of material as was injected into the rabbit which died from the inoculation with anthrax blood taken from the folded blanket. The fact that this rabbit did die shows the virulence of the material, and it is extremely probable that this virulence was destroyed by the disinfectant in the unfolded pieces of blanket, although as stated, this can not be accepted as demonstrated owing to the fact that the *temoin* did not die.

G. M. Sternberg.

EXPERIMENTS ON BURNING SULPHUR IN CLOSED ROOMS, UNDER DIRECTION OF J. H. RAYMOND.*

In these experiments the following points have been considered : The action of sulphur fumes on various ordinary insects and different kinds of cloth, the amount of sulphur which may be burned in a given volume of air, the volume of gases resulting and the nature and extent of the decomposition of sulphurous acid in the presence of moisture after the combustion of the sulphur in the process of disinfection.

* By W. H. KENT, Ph. D., Chemist to the Brooklyn Health Department.

As being closely connected with these subjects we also include in this report the following statement of the physical changes which sulphur undergoes in the process of combustion; this we quote from Lunge's standard work on the Manufacture of Sulphuric Acid:

"Sulphur melts at 111.5° C. (232.7° F.) and forms a thin light-yellow liquid, which on being more strongly heated, becomes darker and thicker; at 250° to 260° C. (480° to 500° F.) it is nearly black, and so viscid that it does not run out when the vessel is upset; at a still higher temperature it becomes thinner again, keeping its brown color; and at 440° C. (824° F.) it boils, forming a brownish red vapor; but it begins to volatilize before boiling."

This is by heating out of contact with the air. When heated in the air the same changes take place until the temperature of combustion is reached, which, according to Lunge is 260° C. (482° F.). It then takes fire and burns with a purplish blue flame, forming SO_2 and giving out 2,221 metrical units of heat.

In consulting the literature of the subject we find a very important article on the Value of Sulphurous Acid as a disinfecting agent by Dr. G. Wolffhügel which in this connection should be noticed. Dr. Wolffhügel* gives experimental work on the following questions:

1st. How may the requisite amount of sulphurous acid be with safety produced by means of burning sulphur in closed rooms?

2nd. What method is best adapted to determine the amount of sulphurous acid in the air, and the amount of gas taken up by the disinfected articles?

3d. To what extent does the sulphurous acid in the air deviate from the amount calculated from the sulphur burned? What are the causes of this deviation and how is the loss to be limited?

4th. Does the gas formed distribute itself uniformly through the room? and do the articles in the room take up a large amount of the gas formed?

5th. Does the gas leave the disinfected articles unin-

* Mittheilungen aus dem Kaiserlichen Gesundheitsamte, Vol. 1, pp. 188—233. Berlin, 1883.

jured, or are they depreciated in value by treatment with sulphur?

6th. What concentration of the gas suffices for the purposes and what arrangement of the experiment is necessary to guarantee the results of disinfection?

Following this article in the same publication (p. 234–282) is also one by Dr. R. Koch in which, in connection with other disinfectants, he considers the amount of sulphurous acid and time necessary to kill certain microscopic organisms.

With this mere notice of the nature of these papers we pass to a description of our own experiments.

For a confined space in which to burn the sulphur a room entirely enclosed by wood was at first used. The pine boards forming the walls, ceiling and floor were generally matched, but in spite of continued calking with rags, its condition as to tightness remained unsatisfactory; however, three experiments with burning sulphur were performed and a part of the desired results obtained. It was then abandoned with the idea that the results with regard to the amount of sulphur which it is possible to burn in a given space would be of no value. We will call this room *Room A*; and the small bed-room with plastered walls which was afterward used *Room B*. Room A was sixteen and one-half feet long, eight and one-third feet wide and eleven feet high, and contained therefore 1,512.5 cubic feet (42,831.8 litres or 42.8318 cubic metres). In one side was a window about two by two and one-half feet; in the adjacent side nearer the floor was also a single pane of glass about eight by ten inches.

Experiment No. 1, Room A.—In a large tin pan holding about twelve quarts (ordinarily known as a dish-pan) was placed an iron kettle holding five and one-half quarts, and supported in the pan by an earthen plate: in the kettle were placed six pounds of broken brimstone and flowers of sulphur, and surrounding it, in the pan, were 8 litres (about 8 quarts) of water. The kettle stood in the water therefore to the extent of about half its height. In the water was placed a maximum and minimum thermometer.

Before the larger window, was suspended in the room, one wire fly trap with about a dozen flies, another with six or eight ants and another with half a dozen croton bugs (*Ectobia Germanica*). The fly traps used in these experiments were made of tinned wire ; those painted with Paris green being in all cases avoided. There was also a thermometer so hung inside the room by the window as to show the temperature of the room from outside. Suspended on a line in about the centre of the room were 116 samples of various kinds of cloth, the coloring matters of which had been determined by Dr. O. Grothe. The samples consisted of :

Eighteen samples of all wool dress-goods (Sicilian cord) dyed with various combinations of logwood black, logwood brown, picric acid, indigo carmine, and Bordeaux.

Eight samples of silk dress-goods (silk cord), which were also variously dyed with Bismarck brown, nigrosine, alkali blue 2 B, Bordeaux, tropæline 3 O No. 2, and roacelline.

Eleven samples of domestic calicoes printed in many figures with catechu brown, logwood black, logwood blue, alizarine red, aniline yellow, and analine blue.

Twelve samples of French satins also printed with aniline black, aniline yellow, alizarine red, indigo, logwood black, fiset wood, cosine, nigrosine, Bordeaux, and alkali blue.

Twenty-four samples of Scotch gingham colored with different combinations of Bismarck brown, logwood black, logwood blue, logwood brown, indigo, aniline blue, aniline yellow, alizarine red, alizarine rosa (tin salts), catechu brown, tropæline O (chrysoine), turmeric, tropæline O 4, fiset wood and vesuvine.

Twenty-four samples of domestic cambrics variously printed with aniline blue, aniline yellow, logwood black, logwood blue, logwood brown, alizarine red, catechu brown, indigo, indigo carmine, naphthaline yellow, induline, and wood blue with chromine.

Three samples of oriental flannels dyed with induline, malachite green, and Bordeaux.

Sixteen samples domestic flannels dyed with Bordeaux, Victoria yellow, fuchsine, methyl violet, logwood black, alizarine red, indnline and brilliant blue (alkali blue 5 B). Duplicate samples of each of these were retained for comparison afterward. Those exposed to the sulphur fumes were numbered the same as the original and with the additional mark of the letter "x".

The sulphur was ignited with burning alcohol and the room closed as soon as possible.

The time necessary for killing the insects as observed from the window outside was as follows.

All flies were dead in 22 minutes ; all ants were dead in 24 minutes ; all Croton bugs were dead in 25 minutes.

The temperature of the room as noted each half hour was as follows :

10.35 A. M.,	73° F.	—at beginning.
11.05 "	85° "	The room became cloudy with smoke so that the burning sulphur could not at all times be seen.
11.35 "	91° "	
12.05 P. M.,	94° F.	
12.35 "	96° "	
1.05 "	97° "	
1.35 "	95° "	—Saw the flame for the last time.
2.05 "	93° "	
2.35 "	90° "	
3.05 "	89° "	
3.35 "	89° "	
4.05 "	88° "	
4.35 "	88° "	
5.05 "	87° "	
5.35 "	86° "	
6.20 "	85° "	

At 8.30 P. M. the room was opened.

Of the 6 lbs. of sulphur introduced 5 lbs. and 9 oz. were burned ; the remaining 4 oz. consisted of sulphur, sulphide of iron, and impurities. Owing to the reduction of temperature, it would not in any case be expected that the sulphur would be completely consumed.

Of the 8 litres of water introduced in the pan, 6.39 litres remained : 1.61 litres were, therefore, evaporated. The temperature of the water which, at the beginning, was 71° F., had risen to 158° F.

The samples of cloth were then arranged in series by the side of the original and exhibited to a number of persons some of whom were experienced dry goods salesmen and were really experts in judging the qualities of fabrics. The general opinion was that as to strength of fibre, no change in any case could be discerned : that as to color, one sample of Sicilian cord, colored with indigo and induline, and one sample of domestic flannel colored with brilliant blue (alkali blue 5 B) were very slightly faded ; that one sample of oriental flannel colored with malachite green was not quite so bright ; that one sample of oriental flannel and one sample of domestic flannel, each colored with induline, were somewhat faded ; that with the remaining 111 samples there was no perceptible change. It is also observed that among the flannels only two were colored with induline, and that these, as above expressed, were the most affected, and that the only piece of woolen dress-goods which contained induline was the one which was very slightly faded.

Experiment No. 2. Room A.—In this experiment an attempt was made to reach the limit of sulphur which might be burned in the room. 32 lbs. 5 oz. of sulphur were placed in two kettles ; one kettle with 16 lbs. 4 oz. placed in the tin pan as before, was surrounded with 8 litres of water, the other with 16 lbs. 1 oz. was placed in a wooden tub, and around it were 25 litres of water. In each case fully one-half of the kettle stood below the surface of the water. There was also suspended in the room, the same as before, a set of samples of the same fabrics from which those before used were taken, numbered the same, and for distinction marked with the letter "Y." The thermometer was also hung before the window, the sulphur ignited with alcohol and the room closed as before.

The temperature was as follows :

1.00 P. M., 122° F.
1.30 " 124° "
2.00 " 124° "
2.30 " 126° "

3.00 P. M., 129° F.
3.30 " 131° "
4.00 " 131° F.—Maximum = 55° C.
4.30 " 130° "
5.00 " 128° "
5.30 " 121° "
6.00 " 115° "
6.30 " 109° "

At 9 P. M. the sulphur ceased burning.

On the following day the room was opened. The sulphur fumes had escaped so that it could be entered immediately. Of the 16 lbs. 4 oz. sulphur placed in one kettle, 6 oz. remained, and of the 16 lbs. 1 oz. placed in the other, 9 oz. remained, or of the 32 lbs. 5 oz., 31 lbs. 6 oz. was burned; the remaining 15 oz. consisted of sulphide of iron, sulphur and impurities.

Since the room contained about 1,500 cubic feet, the amount burned was nearly 21 lbs. per 1,000 feet.

The water surrounding the kettle was found to contain much sulphuric acid. From the following calculation it is concluded that the amount burned was largely in excess of what was necessary to consume the oxygen of the air, and as the sulphur was practically all consumed the room must be considered as not sufficiently tight for the experiment.

The amount of sulphur necessary to completely consume the oxygen in 1,000 *cubic feet of air.*

Since the atomic weight of S is 32, and that of O is 16 (one-half that of S), and since by burning sulphur SO_2 is formed, a compound with one atom of S and two of O, the weight of sulphur in SO_2 is just equal to the weight of oxygen; so the amount of sulphur necessary to completely burn the oxygen of the air is equal to the weight of the oxygen in the air.

One litre of air at O°C weighs 14.43 criths (Cooke) or as 1 crith=.0896 grammes; 1 litre of air weighs 1.2929 grammes. At 55°C. the temperature to which the air was heated by the burning sulphur, 1 litre$=\frac{1.2929}{1+0.00366\times55}=1.0762$ grammes. One cubic foot=28.318 litres or 1,000 cubic feet=28,318 litres. In 1,000 cubic feet there are therefore

30,475.8 grammes or 67.186 pounds of air. As 23.185 per cent. of the air is oxygen the amount of oxygen in 1,000 cubic feet is $67.186 \times 23.185 = 15.577$ lbs. : or, in accordance with the above, 1,000 cubic feet of air would need for the complete burning of the oxygen 15.577 lbs. of sulphur. Of course the low temperature and the highly diluted form the oxygen attains would both tend in practice to greatly reduce this amount.

Vallin * states that experimentally, M. Marty was able to burn only 68 grammes per cubic metre, or about 4.2 lbs. per 1,000 cubic feet, and that Czernicki was able to burn in a large room 300 grammes per cubic metre, or 18.7 lbs. per 1,000 cubic feet. The room in the latter case was undoubtedly not tightly closed as a comparison of his results with the theoretical amount will show. As to the effects on the fabrics in this experiment no difference could be noticed from that of the experiment before given. The samples of cloth in both experiments are arranged in convenient form with those of the original, and may be examined at the office of the Department of Health in Brooklyn.

Experiment No. 3. Room A.—It having been asserted that burning sulphur is not always effective in killing insects, and especially flies on the ceiling, another experiment was made to ascertain with more certainty whether flies are killed uniformly throughout the room, where the usual amount of 3 lbs. of sulphur per 1,000 cubic feet is burned. To this end a window was placed next the ceiling by the upper front left corner of the room, and another by the diagonal corner of the left side next the floor. A fly trap with a number of flies was placed by each window next the ceiling and floor. Flies in traps were also placed at the upper back right corner and on the floor by the diagonal corner of the right side, one was also placed on the centre of the floor, and another on the centre of the ceiling, and one by the window in the centre of the left side. There were also a number of flies, perhaps fifty, confined loose in the room, going where they

*Traité des Désinfectants, p. 243.

chose. An iron kettle, with 4 lbs. and 9 ozs. of sulphur, was placed in water in the large pan, the sulphur ignited, and the room closed as before. The flies next the ceiling, as observed from the window at the upper front left-hand corner were all dead in twenty-three minutes ; those by the large window on the left side also in twenty-three minutes ; those on the floor at the back left-hand corner were dead in fifty minutes ; while some of the flies loose in the room, that had collected mostly by the small window in front near the floor, lived for one hour and forty-five minutes.

The sulphur fumes being heated evidently rose at first to the upper part of the room. The room was then immediately opened, the sulphur extinguished, and as soon as the room could be entered it was found that in all portions of the room which could not be seen from the windows all flies were dead. It would seem, therefore, that when the flies are simply confined in a room not especially tight that they were able by the greater liberty afforded them to withstand the action of the sulphur fumes much longer than when confined to a particular locality in traps. By weighing the kettle and the remaining sulphur it was found that four pounds of sulphur were burned.

Experiment No. 4, Room B.—This room, provided with an ordinary window and door, measured as follows : 8 ft 2 in. long, 6 ft. 2 in. wide, and 7 ft. 7 in. high, containing, therefore, 375 cubic feet. All crevices were thoroughly calked. In an iron pot were placed 16 lbs. 3 oz. sulphur. This was placed in the above described tin pan, and surrounded by nearly 10 litres of water. A maximum and minimum thermometer was hung on the wall showing a temperature at the beginning, of 76° F. In order to ascertain whether sulphuric acid would be formed, and whether the cloud of smoke arising from burning sulphur was due to the formation of this acid, or to sublimed sulphur, or both, a pane of glass 7 x 12 inches, was thoroughly cleaned, wiped dry with a clean cloth and supported horizontally in the middle of the room by a clean glass support. The sulphur was ignited, the door thoroughly

calked, and it being Saturday, P. M., it was left to take its course. The sulphur continued to burn for about 12 hours. When opened on Monday the atmosphere was not endurable. The temperature of the room had risen to 122° F. (50° C.), as shown by the maximum thermometer. Of the 16 lbs. 3 oz. sulphur introduced 2 lbs. 2 oz. had been burned, or at the rate of $5\frac{3}{5}$ lbs. per 1,000 cubic feet. The pane of glass was found to be covered with a fine dew-like deposit, and its extremely sour taste indicated that it must contain sulphuric acid. This was carefully washed with distilled water into a clean flask. The washings unmistakably held sulphur in suspension. The amount of sulphur deposited on the pane of glass was determined after filtering from the H_2SO_4 solution by oxidizing with nitric acid, precipitating and weighing as $BaSO_4$. From this the amount of sulphur deposited on the glass plate was found to be 0.0014 gramme. Since the surface of both sides of the glass pane was 168 square inches, and the surface of the ceiling and floor 14,504 square inches, the amount of sulphur deposited on the ceiling and floor would be 0.1208 gramme. Assuming that it would be deposited on the walls at the same rate, which may not be entirely the case, there would be deposited on the walls, ceiling and floor 0.3817 gramme or 5.88 grains of sulphur. This amount, though not large, is sufficient to account for the slightly dingy appearance of a room immediately after fumigation, and in part also for the cloud of smoke that arises from the burning sulphur. The sulphuric acid in the filtrate as above obtained was precipitated as $BaSO_4$ after the addition of HCl and the $BaSO_4$ filtered and weighed; the H_2SO_4 calculated therefrom was 0.0848 gramme. The amount deposited on ceiling and floor, as calculated from this amount deposited on the pane of glass, is 7.3210 grammes, and assuming as above that it would be deposited at the same rate on the walls of the room there would have been formed 15.2 grammes, or about 234 grains of sulphuric acid.

Experiment No. 5, Room B.—It being sometimes the

practice to place the pot of sulphur on dry ashes instead of in water, the question now arises as to whether by so doing there is the same amount of sulphur burned, and also whether the same amount and relative proportion of sulphuric acid and sulphur are set free as found in the preceding experiment. In order to ascertain these points the following experiment was arranged.

The large tin pan heretofore used was nearly filled with ashes and placed near the middle of the room; on the ashes was placed an iron kettle with 8 lbs. of sulphur. An ordinary pane of glass, 9 by 12 inches, was thoroughly cleaned and horizontally supported about 1½ feet from the floor with a clean glass support. On the wall was also a maximum and minimum thermometer showing a temperature at the beginning of the experiment of 80° F. The sulphur was ignited with burning alcohol and the room thoroughly closed. On opening the room the following day, all smoke had subsided, but sulphur fumes were so strong that it could not be immediately entered. By weighing the pot of remaining sulphur it was found that 2 lbs. 7 oz. had been consumed, or at the rate of 6½ lbs. per 1,000 cubic feet, which as will be noticed, is ⅝ lb. per 1,000 cubic feet more than was burned when the kettle was placed in water. Of course this is due to the fact that the water takes some heat from the kettle and its contents and thereby reduces its temperature. The thermometer on the wall showed a minimum temperature of 73° F. and a maximum temperature of 113° F. On the glass plate was the same dew-like deposit as before, but showing the presence of sulphur much more distinctly. The deposit was carefully removed with distilled water to a glass receptacle, the sulphur filtered therefrom, oxidized with nitric acid, and precipitated with barium chloride. By weighing the precipitate of $BaSO_4$ and calculating the sulphur, it was found that 0.0228 gramme of sulphur had been deposited on the glass plate. Calculating from this the amount deposited on the ceiling and floor would be 1.5301 grammes. If deposited on the walls at the same rate the entire amount formed in the room

would be 4.8352 grammes (74.5 grains). The sulphuric acid in the filtrate from the sulphur thus obtained was precipitated and weighed as $BaSO_4$, from which it was ascertained that 0.1209 gramme H_2SO_4 had been deposited on the plate, or 8.1145 grammes on the ceiling and floor. Calculating as before the total amount deposited in the room would be 25.6397 grammes, or 394.85 grains.

The presence of sulphur and sulphuric acid as found in these experiments is in accordance with the statements of Vallin (p. 243 and 245). He terms the sulphur thus formed, however, sublimed sulphur, or sulphur vaporized from the original mass and escaping the flame without being burned. From the following it will hardly appear that it is sublimed sulphur. According to Richter sulphurous acid in aqueous solution gradually undergoes the following reaction :

$$3SO_2+2H_2O=2H_2SO_4+S,$$

from which we would see that sulphur and sulphuric acid are formed by the action of sulphurous acid on water, and in the proportion of 196 parts of sulphuric acid to 32 parts of sulphur. The conditions in the case of burning sulphur for disinfecting purposes differs from these only in this, that the sulphurous acid and water are in the gaseous form. The relation of the amount of sulphuric acid and sulphur deposited on the glass plates in these experiments may be taken as approximately expressing the relation of the total amounts formed, and this relation is sufficiently near that of 196 to 32 to make it probable that it is formed, mostly at least, from the decomposition of sulphurous acid.

Another point of chemical interest and which may have some practical bearing in this connection is the fact that much more sulphur and sulphuric acid are formed when ashes are used than when the receptacle for the burning sulphur stands in water. In all those cases where the burning sulphur was surrounded by water it has been observed that a considerable amount of water is evaporated. The atmosphere of the room must therefore be charged with moisture.

It is known in the ordinary method of making sulphuric acid that an excess of water or steam interferes with the oxidation of the sulphurous acid ; and, although the conditions are not the same in the two cases, the results above obtained show a resemblance in this respect.

As to the amount of water present when ashes are used, we know there is always a small amount of moisture in ordinary air, and that when alcohol is used to ignite the sulphur as in these cases, some water is formed by the combustion of alcohol ; so it is apparent that there is a considerable amount of water present to carry out the decomposition of the sulphurous acid. A fact of ordinary observation in a chemical laboratory is that a solution of sulphurous acid in water only very gradually undergoes decomposition and that even in the presence of strong light some weeks may be necessary to make much change ; this would corroborate the conclusion we would draw that an excess of water interferes with the decomposition of sulphurous acid ; that if the presence of sulphuric acid is necessary to kill the organisms, the amount may be increased by avoiding the presence of too much water ; and that if the formation of sulphuric acid is to be avoided, placing the receptacle for the sulphur in water is very effective to that end.

The Effect of Burning Sulphur on the Volume of Air Confined.—By burning sulphur in hermetically closed places, the question as to whether the volume will become changed so as to cause an injury to the walls, or possibly an explosion, is considered as follows :

Since by the consumption of the O_2 of the air, SO_2 is formed, and since to form one molecule of SO_2 one molecule of O_2 is necessary ;

We have formed according to the equation,

$$S + 2O_2 = 2\ SO_2,$$

as many molecules of SO_2 as is consumed of O_2, and so according to Avogadro's law, the volume of SO_2 formed is equal to the volume of O_2 consumed, or in other words there is no increase or decrease in the volume of the air except that which comes as expansion by heat.

It being very seldom that perfectly tight compartments are found, and as gases in general are so very elastic, the amount of pressure exerted on the walls by such expansion would in most cases be insufficient to do any damage.

SULPHITES.

By George M. Sternberg.

Sodium Sulphite and Sodium Hyposulphite.—My experiments made at San Francisco (*American Journal of the Medical Sciences*, April, 1883) show that these salts in concentrated solution have no germicide power. The micrococcus of pus was not killed by exposure for two hours to a thirty-two per cent. solution, and a saturated solution failed to destroy the bacteria in broken-down beef-tea. Arloing, Cornevin, and Thomas found that exposure for forty-eight hours to a fifty per cent. solution of sodium hyposulphite does not destroy the virus of symptomatic anthrax. It is evident, from the experimental evidence on record, that these salts have no value, either as germicides or as antiseptics, *except in the presence of some chemical agent which will liberate the sulphurous acid.*

Bisulphite of Lime, Bisulphite of Zinc, Bisulphite of Soda, Tersulphite of Aluminium. — A manufacturing chemist of New York sent me, last spring, samples of the above-mentioned salts in solution, and I made a number of tests to determine their comparative germicide power. The results obtained indicate that their value as disinfectants depends upon the amount of sulphurous acid which they contain. All of the solutions gave off sulphurous acid gas constantly when not kept in tightly corked bottles ; and, in adding them to broken down beef-stock, an abundant liberation of this gas occurred.

The solution of bisulphite of lime gave the best results.

In the proportion of five per cent. this destroyed the vitality of *M. tetragenus*, the test organism employed. The solution of bisulphite of zinc and tersulphite of aluminium failed to destroy the same micrococcus in the proportion of five per cent., but were successful in ten per cent. The solution of bisulphite of soda failed upon the same organism in ten per cent. I have lost my memorandum giving the specific gravity of these solutions, but believe them to have been saturated solutions of the salts named.

DRY HEAT.

By George H. Rohé.

The first accurate observations on the disinfecting power of dry heat were made by Henry, of Manchester, in 1831. (Quoted in E. Vallin: *Traite des Desinfectants*, Paris, 1882, p. 226). Henry exposed (fresh ?) vaccine virus to temperatures varying from 50° to 82° Cent. (122°–180° Fahr.) for two, three, and four hours, and secured complete disinfection, none of the specimens of vaccine thus exposed producing vaccinia when subsequently inoculated. Exposure for three hours to a temperature of 49° C. (120° F.) failed to disinfect. No control experiments with non-disinfected virus were made by this observer.

E. B. Baxter (*Report Medical Officer of Privy Council*, etc., N. S., No. vi. p. 216) exposed dry vaccine to a temperature of from 90°–95° C. (194°–203° F.), for thirty minutes. Disinfection was complete. Vaccination with disinfected virus was unsuccessful. Control inoculations with non-disinfected virus were successful.

Carstens and Coert reported to the International Hygienic Congress of 1879 (quoted by Vallin, in the above-mentioned work) the following conclusions:

Fresh animal vaccine heated to 64.5° C. (148° F.) for thirty minutes loses its virulence. Fresh animal vaccine heated to 52° C. (125° F.) for thirty minutes does not lose

its virulence. The maximum degree of heat to which fresh vaccine can be exposed without losing its infectivity probably varies between 52° and 54° C. (125°–129° F).

Davaine, in 1873, destroyed the virulence of fresh anthrax blood * by exposing it to temperatures of 55° C. (131° F.) for five minutes, 50° C. (122° F.) for ten minutes, and 48° C. (118° F.) for fifteen minutes.

Werner, in 1879, exposed putrefactive bacteria on pledgets of cotton and then enveloped in dry cotton to a temperature of 125° C. (257° F.) for one hour, and secured complete disinfection.

Wernich (*Deutsche Med. Wochenschr.*, 1880, p. 498) exposed putrid material (containing bacteria of putrefaction) to temperatures of from 125°–150° C. (257°–302° F.) for five minutes with like success.

Schill and Fischer (*Mitth. a. d. Kais. Gesundheitsamte*, Bd. II. S. 134) found that exposure for one hour to a temperature of from 100°–130° C. (212°–266° F.) destroyed the virulence of tuberculous sputum, as tested by the inoculation of rabbits and other animals.

Koch and Wolffhügel (*Mitt. a. d. Kais. Gesundheitsamte*, Bd. I.) experimented with a large number of pathogenic and non-pathogenic organisms. A temperature varying from 78°–123° C. (172°–253° F.) maintained for one hour and a half (over 212° F. for an hour) sufficed to kill micrococcus prodigiosus and the bacilli of septicæmia of mice and rabbits, but failed to destroy the spores of bacillus anthracis and of various non-pathogenic bacteria and fungi.

Micrococci and bacilli containing no spores, and spores of mould fungi, were completely killed by one and a half hour's exposure to a temperature of from 120°–128° C. (248°–262° F.) ; but spores of B. subtilis, B. anthracis, and of a bacillus growing upon potato, resisted a second heating to the same temperature for a similar length of time.

These authors further experimented upon a number of organisms disposed in various ways in the disinfecting

*Containing bacilli, but no spores.

chamber, so as to approach in a measure the conditions of practical disinfection. Some of the articles were placed in coat pockets, others rolled up in balls of cotton, oakum, blankets, or soiled clothing, making packages of different thickness and density. The organisms consisted of micrococcus prodigiosus, micrococcus of blue pus, bacillus anthracis, and bacilli found in garden soil. With each package was placed a registering thermometer to indicate the highest temperature reached during the experiment. The temperature in the chamber varied from 133° to 156° C. (271°–313° F.), and the exposure was continued for three hours and ten minutes. The temperature in the different packages varied from 74.5° C. (167° F.) to 121.5° C. (251° F.). In none of the packages were the spore-bearing organisms destroyed. In a small iron vessel hanging free in the chamber and containing specimens of the same organisms, a temperature of 139.5° C. (283° F.) was indicated by the thermometer. Here complete disinfection had taken place.

Another series of observations, with the temperature in the chamber varying from 131°–140° C. (267°–284° F.), and exposure continuing for three hours, resulted as follows: The organisms (micrococcus prodigiosus, spores of bacillus anthracis, and of bacilli of garden soil) and registering thermometers were enclosed in packages of clothing, bedding, and rolls of blankets. Complete destruction of the spore-bearing organisms did not follow unless the temperature of 139° C. (282° F.) had been reached. In one large package consisting of nineteen blankets, thoroughly dried and rolled up, the heat did not penetrate to the interior in a sufficiently high degree to destroy the vitality of micrococcus prodigiosus even.

These experiments were still further varied, but the results did not differ materially from those already given. They all showed the great difficulty of penetration of thick packages of fabrics of various kinds by a sufficiently high temperature to produce disinfection.

A large number of fabrics (linen, silk, cotton, wool, feathers, paper, and leather) were exposed for five hours

to a temperature of from 150°–160° C. (302°–320° F.) with the result of producing such changes in color and texture of most of them so as to render them useless.

In a similar series of experiments, Ransom (*Practitioner*, 1878, p. 67) found that exposure to a temperature of from 240°–250° F. would be borne by clothing materials without injury. Vallin (*op. cit.*) states that cotton and wool fabrics do not change color at a lower temperature than 125° C. (253° F.), which corresponds closely with the observations of Ransom.

Koch and Wolffhügel (*op. cit.*, p. 231) submit the following conclusions, which seem to the writer to be fully justified by the results of their own and other observations here collected :

1. A temperature of 100° C. (212° F., dry heat), maintained for one hour and a half, will destroy bacteria which do not contain spores.

2. Spores of mould-fungi require for their destruction in hot air, a temperature of from 110°–115° C. (230°–239° F.) maintained for one hour and a half.

3. Bacillus spores require for their destruction in hot air, a temperature of 140° C. (284° F.) maintained for three hours.

4. In dry air the heat penetrates objects so slowly that small packages, such as a pillow or small bundle of clothing, are not disinfected after an exposure of from three to four hours, to a temperature of 140° C. (284° F.).

5. Exposure to a temperature of 140° C. (284° F.) in dry air for a period of three hours injures most objects requiring disinfection (clothing, bedding, etc.) to a greater or less degree.

MOIST HEAT.

By George M. Sternberg.

Whenever infectious material can be consumed by fire, there can be no question as to the efficiency of this mode of disposing of it. But from the experimental data given in the preceding paper, it will be seen that the destruction

of desiccated spores by dry heat requires a temperature which injures textile fabrics.

It is quite different with moist heat, and in steam, at a temperature of from 105° to 110° C. (221° to 230° F.), we have an agent which quickly destroys all living organisms, including the most refractory spores.

In the absence of spores, all known micro-organisms are quickly destroyed when immersed in boiling water. Indeed, a temperature much below the boiling-point destroys micrococci and bacilli in active growth. Thus I have fixed the thermal death-point of the micrococcus of septicæmia in the rabbit, and of the micrococcus of pus (from an acute abscess) at 140° F. (60° C.), the time of exposure being ten minutes. This temperature is also fatal to the micrococcus of swine plague. The micrococcus of fowl-cholera is destroyed by exposure for fifteen minutes to a temperature of 132° F. (Salmon). Nine or ten minutes' exposure to a temperature of 54° C. (129.2° F.) is sufficient to destroy the vitality of anthrax bacilli in blood (Chauveau). Davaine has shown that, owing to the low thermal death-point of this bacillus, it may be destroyed in an inoculation wound by application of heated metal to the surface—hammer of Mayor. May it not be that the *rationale* of the effect of poultices applied "as hot as can be borne" to furuncles, acute abscesses, etc., is to be explained in the same way? Or, at least, if a temperature sufficient to destroy the vitality of micrococci which have invaded the tissues cannot be borne, is it not probable that their multiplication may be prevented by the continued application of a bearable temperature?

The resisting power of spores is very much greater, and it is well known that the spores of *B. subtilis* and of other species of the genus *Bacillus* withstand a boiling temperature for a considerable time. My culture-fluids have frequently "broken down," on account of the presence of the spores of *B. subtilis*, after two hours' boiling, and, to insure sterilization, I am in the habit of resorting to a second boiling, after an interval of twelve hours, or of sterilizing in a bath containing some salt by

which a higher temperature than that of boiling water can be secured.

A temperature of five degrees Centigrade (9° F.) above the boiling point quickly destroys the most refractory spores. I have recently made numerous experiments upon the spores of *B. anthracis* and *B. subtilis*, which show that the former has less resisting power than the latter, but that both are destroyed with a temperature of 105° C. maintained for ten minutes. The same temperature failed to destroy the developing power of the spores of *B. subtilis* in five minutes, while two minutes' exposure destroyed the vitality of anthrax spores.

These results are in accord with those of Koch, Gaffky, and Loeffler,* who found, as the result of numerous experiments, that when a temperature of 105° and upward was maintained for ten minutes, all spores were destroyed, as shown by their failure to develop in culture-solutions. Where a temperature of 110° C. was reached, the experiment could be stopped, as no spores were capable of germinating after exposure to this temperature. Exposure to a temperature of 100° to 105° C. for twenty or thirty minutes was fatal to anthrax spores, but those of a certain short and thick bacillus found in garden soil were only killed when the temperature was maintained at 105° for twenty minutes.

The question as to the practicability of destroying spores in the interior of packages—rolls of blankets, etc., has received the attention of the experimenters last mentioned, and will doubtless be considered by my colleagues of the Committee on Disinfectants, whose province it is to take account of the various points which may arise relating to the practical use of approved disinfecting agents.

From the experimental evidence presented, it is safe to say that :

The temperature of boiling water will quickly destroy the vitality of all micro-organisms of the class to which known disease germs belong, in the absence of spores.

* Mitt. a. d. Kaiserlichen Gesundheitsamte, vol. 1. pp. 322-40.

Steam at a temperature of 110° C. (230° F.) maintained for one or two minutes, or of 105° C. (221° F.) maintained for ten minutes, will infallibly destroy the spores of bacilli, which constitute the most difficult test of disinfecting power known.

NOTE.—I desire to call attention to the close correspondence between the thermal death-point of micrococci as fixed by my experiments, viz., 140° F. for ten minutes, and the results obtained by the authors quoted by Dr. Rohé in the preceding paper, in the disinfection—*i. e.*, destruction of specific infecting power—of fresh vaccine virus by similar low temperatures. Certainly this correspondence gives some support to the supposition that infective virulence is due to the presence of the micrococcus found in vaccine lymph, although the etiological role of this micrococcus has never been demonstrated by successful inoculations with pure cultures.

ON THE DISINFECTANT PROPERTIES OF PUTREFACTIVE PRODUCTS.

BY CHARLES SMART.

IT is well known that, when a saccharine liquid undergoing fermentation has attained a certain alcoholic strength, the further growth of the yeast plant is prevented by the action of its alcoholic product. It is, perhaps, equally well known that an inhibition of the acetous fermentation takes place when the liquid has reached a certain percentage of acetic acidity. But it is not so generally known that the bacteria of putrefaction elaborate, as products of their vital action, organic substances that are destructive to the organisms which determined their formation. The ultimate products in the retrogression of albuminous matters by bacterial or putrefactive agency are ammonia and carbonic acid ; but a vast number of complex organic substances, concerning which our knowledge is meagre, constitute intermediate steps in the process. One of these, phenol, or carbolic acid, was

at the time of its discovery as a product of putrefaction already well known as an antiseptic, and probable disinfectant. Recently E. and H. Salkowski separated from these intermediate products two aromatic acids of the acetic series, hydrocinnamic or phenyl-propionic and phenyl-acetic acid.

Wernich * submitted these to experiment, and found that as antiseptics they were superior to carbolic acid, the phenyl-propionic acid being the more active of the two. Klein † followed up these researches by an inquiry into their germicidal value. Some of his experiments bear with greater interest on the life history of the organisms subjected to the influence of the acids than on the germicidal value of the latter ; but, to complete this series of papers, it has been deemed advisable to submit a summary of his results.

This able experimenter recognized the difference between antisepsis and disinfection that has been insisted upon in the reports of this Committee. He exposed the organisms that were the subject of the experiment to the action of the acids, and then introduced them into a suitable culture medium ; or, if they were of a pathogenic nature, inoculated animals with them,—a failure to cultivate, or a failure to reproduce the disease being respectively in each case the test of a germicidal or truly disinfectant action.

The non-specific organisms subjected to experiment were a small micrococcus derived from the blood of rabbits, a large micrococcus of similar derivation, bacterium termo and *Bacillus subtilis*. An exposure of twenty or twenty-five minutes in a solution of either acid of the strength 1 : 200, failed to destroy the vitality of any of these specimens ; the last mentioned, indeed, was not destroyed by an exposure of twenty-four hours.

The pathogenic matters treated were the spores and bacilli of anthrax, the virus of swine-plague, and that of tuberculosis.

* Virchow's Archiv, vol. 78, p. 51.

† Supplement to Thirteenth Annual report of Local Government Board, London, 1884, p. 111.

Anthrax *spores*, exposed for two or more days in either acid of the strength 1 : 400, were found to have retained their virulence when subsequently injected into guinea-pigs, and to be susceptible of cultivation in culture liquids, with the retention of virulence in their progeny. But, although the spores withstood the influence of the acids, the *bacilli* of anthrax were killed immediately, or as soon as they were thoroughly mixed with this strength of either of the acids. The phenyl-propionic acid, however, was manifestly more efficient, for a dilution of 1 : 800 destroyed the bacilli in ten minutes, while the phenyl-acetic acid under similar conditions failed to accomplish disinfection. Greater dilutions required a longer period to effect the destruction of the bacilli and in all instances the phenyl-propionic acid showed the greater potency. Thus while this acid, in the strength 1 : 3,200, required from twenty-five to thirty-five minutes to be effective, the phenyl-acetic acid of the same strength required fully thirty-five minutes.

Several other points of interest were developed. It was noted that in greater dilutions than 1 : 400 of either acid, a stronger solution or a longer exposure was required to kill bacilli grown from a previous culture containing spores than those from a culture started from blood bacilli. It was observed further that bacilli cultivated from bacilli of the blood have a greater resistance than the latter, so far as these acids are concerned, for the first week or ten days of the cultivation, but that after this their power of resistance decreases, so that ultimately it becomes even less than that of the original blood bacillus. The fact was also shown that bacilli in the blood of a guinea-pig dead from inoculation with spores have a greater resistance to the influence of the acid than those from an animal dead from inoculation with bacilli.

The virulence of swine-plague, taken directly from an animal dead of the disease, and also that of the artificially cultivated microbe, were destroyed by an exposure of twenty or twenty-five minutes to a phenyl-propionic solu-

tion of the strength 1 : 800 ; weaker solutions were not efficient, and the disinfectant action of the phenyl-acetic acid of this strength was not certain.

The tubercular virus, like the spores of anthrax, resisted the influence of these acids. An exposure of ninety-six hours to a strength 1 : 200 did not prevent the caseous matter of pulmonary tuberculosis from producing its characteristic effects when injected into a guinea-pig. But considerably stronger solutions showed the exercise of an inhibitory power. Bovine virus manifested a greater resistance against the influence of the acids than the tuberculous virus of man.

PRACTICAL EXPERIMENTS ON THE STERILIZATION OF FECES.

By George M. Sternberg.

In the experimental researches heretofore recorded in this series of papers the germicidal value of various chemical reagents has been established by biological tests made with pure cultures of various micro-organisms or with "broken-down" beef-tea. The latter test I consider the most difficult, as the putrid beef-tea, after having been exposed in the laboratory for several days, contains a variety of micro-organisms, including several species of bacilli, especially *B. subtilis*, the spores of which have an extreme resistance. The results obtained in these experiments may, therefore, be safely used as a basis for determining the quantity of the chemical agents tested which will be necessary to sterilize *fluids* containing micro-organisms, when these fluids can be fairly compared with the putrid beef solution used in our experiments—due allowance being made on the side of safety when practical recommendations are to be made. The liquid discharges from the bowels of patients with cholera, typhoid fever, advanced tuberculosis, septic diarrhœa, etc., may be fairly compared with our broken-down beef-tea.

as regards physical and biological characters, and I should say, in general, that it would be within the limits of safety to prescribe twice the quantity of a given agent, for the disinfection of such material, that has been found necessary to sterilize the same amount of putrid beef stock.

But when we have to deal with formed or semi-solid fecal matter the conditions are very different, and the data obtained in our experiments upon fluid material cannot be applied without making proper allowance for the larger amount of organic material associated with the germs which are to be destroyed, and for the fact that germs enclosed in masses of albuminous material may be protected from the action of the disinfecting agent. Especial care will be required in the practical use of the oxidizing disinfectants, such as potassium permanganate and the hypochlorites of lime and of soda. These agents owe their power to the fact that they are promptly decomposed by contact with organic matter, but this decomposition is entirely a chemical reaction, and only a given amount of organic material can be oxidized by a given quantity of the oxidizing agent ; on the other hand, the disinfecting power of such agents is neutralized by a given quantity of organic material, whether this is in the form of living micro-organisms, or of dead animal or vegetable matter. If, then, the organic material is in excess, germs embedded in it will escape destruction, and the only safe rule in the practical use of oxidizing disinfectants is to *use such a quantity of the disinfecting agent that it shall be in excess after the reaction has taken place.*

The following experiments have been made for the purpose of determining within the limits necessary for practical purposes the quantity of the disinfecting solutions heretofore recommended by the Committee on Disinfectants required to sterilize a given quantity of feces (normal).

Standard Solution No. 1.

August 25.—Four ounces of semi-solid feces added to *one pint* of standard solution No. 1, available chlorine

0.65 per cent. At the end of twenty-four hours no chlorine remained in the mixture, and two culture-flasks inoculated with the material broke down—failure to sterilize.

28*th.*—Four ounces of semi-solid feces added to *one quart* of standard solution No. 1, containing 0.85 per cent. of available chlorine. At the end of twenty-four hours a trace of chlorine (0.01 per cent.) remained; there was no appearance or odor of feces in the mixture—no cultures were made in this experiment.

31*st.*—Seven ounces of semi-solid feces added to *two quarts* of standard solution No. 1, available chlorine 0.83 per cent. At the end of one hour there was a trace of chlorine in the mixture. Two culture-flasks inoculated remained sterile.

September 5.—Two and one-half ounces of semi-solid feces added to *one quart* of standard solution No. 1, available chlorine 0.9 per cent. At the end of one hour the mixture was found to contain 0.1 per cent. of available chlorine. Two culture-flasks were inoculated at the end of one hour; both broke down after remaining twenty-four hours in the oven. As both flasks contained a pure culture of *B. subtilis* it was evident that this was the most resistant organism present in the material, and that all other organisms were destroyed.

7*th.*—Six and one-half ounces of semi-solid feces added to *two quarts* of standard solution No. 1, containing 0.9 per cent. of available chlorine. At the end of three hours the available chlorine present in the mixture was found to be 0.11 per cent., and at the end of twenty-four hours 0.1 per cent. Two tubes inoculated at the end of three hours remained sterile.

I conclude from these experiments that in practice it will be safe to use one quart of standard solution No. 1 for every two ounces of feces to be sterilized. Vallin estimates a complete (daily) evacuation of the bowels at from 150 to 200 grammes—say six to eight ounces. Let us keep on the safe side and allow one gallon of this solution, containing four ounces of chloride of lime of the best quality for the sterilization of a nor-

mal alvine evacuation. The daily cost *per capita.* for sterilizing feces would then be less than one cent, for chloride of lime can be bought by the quantity for three and a half cents per pound.

Standard Solution No. 2.

August 30.—Two and one-half ounces of semi-solid feces added to *one pint* of standard solution No. 2. The material was very completely deodorized by the potassium permanganate in the solution. A thorough admixture and breaking up of the fecal matter was effected in this and in the following experiments by stirring with a glass rod. Two culture-flasks were inoculated at the end of two hours; both remained sterile.

September 6.—Seven and one-half ounces of semi-solid feces added to *one quart* of standard solution No. 2. There was a decided fecal odor at the end of twenty-four hours. Two culture-flasks inoculated at the end of twenty-four hours broke down with *B. termo.*

8th.—Seven ounces of semi-solid feces added to *two quarts* of standard solution No 2. Only a slight fecal odor at the end of twenty-four hours. A copper wire dipped into the mixture showed the presence of a salt of mercury in solution—deposit of metallic mercury on wire. Two culture-tubes inoculated in twenty-four hours remained sterile.

Making a liberal allowance on the side of safety, we may say that one gallon of this standard solution, containing two drachms each of mercuric chloride and potassium permanganate, may be relied upon for sterilization and deodorization of a normal alvine evacuation. The cost would be about two cents, if the materials were purchased by the quantity, and the solution made (without expense for transportation) as required.

The following experiments have been made with a solution containing four ounces of mercuric chloride and one pound of cupric sulphate to the gallon of water (standard concentrated solution). For use, this standard solution is diluted by adding eight fluid-ounces to the gallon of water.

August 29.—Eight ounces of semi-solid feces added to *one quart* of above solution. Fecal odor not destroyed as well as by standard solution No. 2. Two culture-flasks inoculated at the end of twenty-four hours remained sterile.

September 2.—Three ounces of formed feces added to one quart of the above mentioned solution. Two culture-flasks inoculated at the end of twenty-four hours remained sterile.

The following experiment has been made with solution of carbolic acid.

2*d*.—One and one-half ounces of formed feces added to *one quart* of a 5 per cent. solution of carbolic acid. Two culture-flasks inoculated at the end of twenty-four hours broke down with *B. subtilis, a pure culture*, showing that the spores of this bacillus had not been killed, but that the material had been sterilized so far as *B. termo*, and other putrefactive organisms present, were concerned.

CONCLUSIONS.

The experimental evidence recorded in this report seems to justify the following conclusions :

The most useful agents for the destruction of spore-containing infectious material are :

1. *Fire.* Complete destruction by burning.
2. *Steam under pressure.* 110° C. (230° Fahr.) for ten minutes.
3. *Boiling in water* for one hour.*
4. *Chloride of lime.*† A 4% solution.
5. *Mercuric chloride.* A solution of 1 : 500.

For the destruction of infectious material which owes its infecting power to the presence of micro-organisms *not containing spores*, the Committee recommends :

1. *Fire.* Complete destruction by burning.
2. *Boiling in water* half an hour.
3. *Dry heat.* 110° C. (230° Fahr.) for two hours.
4. *Chloride of lime.*† 1 to 4% solution.
5. *Solution of chlorinated soda.*‡ 5 to 20% solution.
6. *Mercuric chloride.* A solution of 1 : 1000 to 1: 4000.
7. *Sulphur dioxide.* Exposure for 12 hours to an atmosphere containing at least 4 volumes per cent. of this gas, preferably in presence of moisture.§
8. *Carbolic acid.* 2 to 5% solution.
9. *Sulphate of copper.* 2 to 5 % solution.
10. *Chloride of zinc.* 4 to 10% solution.

The Committee would make the following recommendations with reference to the practical application of these agents for disinfecting purposes :

* This temperature does not destroy the spores of *B. subtilis* in the time mentioned, but is effective for the destruction of the spores of the anthrax bacillus and of all known pathogenic organisms.

† Should contain at least 25 per cent. of available chlorine.

‡ Should contain at least 3 per cent. of available chlorine.

§ This will require the combustion of between 3 and 4 lbs. of sulphur for every 1000 cubic feet of air space.

For Excreta.

(*a.*) In the sick room:

For spore-containing material;

1. Chloride of lime in solution, 4%.
2. Mercuric chloride in solution, 1 : 500.*

In the absence of spores;

3. Carbolic acid in solution, 5%.
4. Sulphate of copper in solution, 5%.
5. Chloride of zinc in solution, 10%.

(*b.*) In privy vaults:

Mercuric chloride in solution, 1 : 500.†

(*c.*) For the disinfection and deodorization of the surface of masses of organic material in privy vaults, etc.:

Chloride of lime in powder.‡

For Clothing, Bedding, etc.

(*a.*) Soiled under-clothing, bed linen, etc.:

1. Destruction by fire, if of little value.
2. Boiling for at least half an hour.
3. Immersion in a solution of mercuric chloride of the strength of 1 : 2000 for four hours.§
4. Immersion in a two per cent. solution of carbolic acid for four hours.

(*b.*) Outer garments of wool or silk, and similar articles, which would be injured by immersion in boiling water or in a disinfecting solution:

(1.) Exposure to dry heat at a temperature of 110° C. (230° Fahr.) for two hours.

(2.) Fumigation with sulphurous acid gas for at least twelve hours, the clothing being freely exposed, and the gas present in the disinfection chamber in the proportion of four volumes per cent.

---

* The addition of an equal quantity of potassium permanganate as a deodorant, and to give color to the solution, is to be recommended (*Standard Solution No. 2.*)

† A concentrated solution containing four ounces of mercuric chloride and one pound of cupric sulphate to the gallon of water is recommended as a *standard solution*. Eight ounces of this solution to the gallon of water will give a dilute solution for the disinfection of excreta, containing about 1 : 500 of mercuric chloride and 1 : 125 of cupric sulphate.

‡ For this purpose the chloride of lime may be diluted with plaster of Paris, or with clean, well-dried sand, in the proportion of one part to nine.

§ The blue solution containing sulphate of copper, diluted by adding two ounces of the concentrated solution to a gallon of water, may be used for this purpose.

(*c.*) Mattresses and blankets soiled by the discharges of the sick:

1. Destruction by fire.

2. Exposure to super-heated steam—25 lbs. pressure—for one hour. (Mattresses to have the cover removed or freely opened.)

3. Immersion in boiling water for one hour.

4. Immersion in the blue solution (mercuric chloride and sulphate of copper) two fluid ounces to the gallon of water.

Furniture and Articles of Wood, Leather and Porcelain.*

Washing, several times repeated, with:

1. Solution of mercuric chloride 1 : 1000. (The blue solution, four ounces to the gallon of water, may be used.)

2. Solution of chloride of lime, 1%.

3. Solution of carbolic acid, 2%.

For the Person.

The hands and general surface of the body of attendants, of the sick, and of convalescents at the time of their discharge from hospital:

1. Solution of chlorinated soda diluted with nine parts of water (1 : 10.)

2. Carbolic acid, 2% solution.

3. Mercuric chloride, 1 : 1000: recommended only for the hands, or for washing away infectious material from a limited area, not as a bath for the entire surface of the body.

For the Dead.

Envelope the body in a sheet thoroughly saturated with:

1. Chloride of lime in solution, 4%.

2. Mercuric chloride in solution, 1 : 500.

3. Carbolic acid in solution, 5%.

For the Sick Room and Hospital Wards.

(*a.*) While occupied, wash all surfaces with:

* For articles of metal use Solution No. 3.

1. Mercuric chloride in solution, 1 : 1000, (the blue solution containing sulphate of copper may be used.)
2. Chloride of lime in solution, 1%.
3. Carbolic acid in solution, 2%.

(*b.*) When vacated :

Fumigate with sulphur dioxide for 12 hours, burning 3 pounds of sulphur for every 1000 cubic feet of air space in the room ; then wash all surfaces with one of the above-mentioned disinfecting solutions, and afterward with soap and hot water ; finally throw open doors and windows and ventilate freely.

For Merchandise and the Mails.*

The disinfection of merchandise and of the mails will only be required under exceptional circumstances ; free aeration will usually be sufficient. If disinfection seems necessary, fumigation with sulphur dioxide, as recommended for woolen clothing, etc., will be the only practicable method of accomplishing it.

Rags.

(*a.*) Rags which have been used for wiping away infectious discharges should at once be burned.

(*b.*) Rags collected for the paper-makers during the prevalence of an epidemic should be disinfected before they are compressed in bales by:—

1. Exposure to super-heated steam (25 lbs. pressure) for ten minutes.
2. Immersion in boiling water for half an hour.

(*c.*) Rags in bales can only be disinfected by injecting super-heated steam (50 lbs. pressure) into the interior of the bale. The apparatus used must insure the penetration of the steam to every portion of the bale.

Ships.

(*a.*) Infected ships at sea should be washed in every accessible place, and especially the localities occupied by the sick, with :—

* In order to secure penetration of the envelope by the sulphur dioxide, all mail matter should be perforated by a cutting stamp before fumigating,

1. Solution of mercuric chloride 1:1000 (the blue solution heretofore recommended may be used).

2. Solution of chloride of lime 1 %.

3. Solution of carbolic acid 2 %.

The bilge should be disinfected by the *liberal* use of a strong solution of mercuric chloride (the concentrated solution—"blue solution"—of this salt with cupric sulphate may be used).

(*b.*) Upon arrival at a quarantine station an infected ship should at once be fumigated with sulphurous acid gas, using three pounds of sulphur for every 1000 cubic feet of air space; the cargo should then be discharged on lighters; a liberal supply of the concentrated solution of mercuric chloride (4 oz. to the gallon) should be thrown into the bilge, and at the end of twenty-four hours the bilge water should be pumped out and replaced with *pure* sea-water; this should be repeated. A second fumigation after the removal of the cargo is to be recommended; all accessible surfaces should be washed with one of the disinfecting solutions heretofore recommended and subsequently with soap and hot water.

At the annual meeting of the *Sanitary Council of the Mississippi Valley*, held in New Orleans, La., March 10—11, 1885, the following resolution was adopted :—

"*Resolved*, That the Secretary request from the Chairman of the Committee on Disinfectants, appointed at the last meeting of the American Public Health Association, a plain, practical paper on Disinfection and Disinfectants, for popular use and distribution, to be furnished to the Chairman of the special committee of this Council on General Sanitation."

In compliance with this request a *Preliminary Report* was prepared, which has been quite widely circulated.

This report having been made before the experimental researches of the Committee were completed, and being a "preliminary report," was only intended to serve a temporary purpose; but it has been thought best to revise it, and to introduce it into this our final report, so that it may be available for distribution in a separate form if sanitary officials find it suitable for popular use.

DISINFECTION AND DISINFECTANTS.

The object of *disinfection* is to prevent the extension of infectious diseases by destroying the specific infectious material which gives rise to them. This is accomplished by the use of *disinfectants*.

There can be no partial disinfection of such material; either its infecting power is destroyed or it is not. In the latter case there is a failure to disinfect. Nor can there be any disinfection in the absence of infectious material.

It has been proved for several kinds of infectious material that its specific infecting power is due to the presence of living micro-organisms, known in a general way as "disease germs;" and practical sanitation is now based upon the belief that the infecting agents in all kinds of

infectious material are of this nature. Disinfection, therefore, consists essentially in the destruction of disease germs.

Popularly, the term disinfection is used in a much broader sense. Any chemical agent which destroys or masks bad odors, or which arrests putrefactive decomposition is spoken of as a disinfectant. And in the absence of any infectious disease it is common to speak of disinfecting a foul cess-pool, or bad smelling stable, or privy vault.

This popular use of the term has led to much misapprehension, and the agents which have been found to destroy bad odors—*deodorizers*—or to arrest putrefactive decomposition—*antiseptics*—have been confidently recommended and extensively used for the destruction of disease germs in the excreta of patients with cholera, typhoid fever, etc.

The injurious consequences which are likely to result from such misapprehension and misuse of the word disinfectant will be appreciated when it is known that:

Recent researches have demonstrated that many of the agents which have been found useful as deodorizers, or as antiseptics, are entirely without value for the destruction of disease germs.

This is true, for example, as regards the sulphate of iron or copperas, a salt which has been extensively used with the idea that it is a valuable disinfectant. As a matter of fact, sulphate of iron in saturated solution does not destroy the vitality of disease germs or the infecting power of material containing them. This salt is, nevertheless, a very valuable antiseptic, and its low price makes it one of the most available agents for the arrest of putrefactive decomposition in privy vaults, etc.

Antiseptic agents, however, exercise a restraining influence upon the development of disease germs, and their use during epidemics is to be recommended, when masses of organic material in the vicinity of human habitations can not be completely destroyed, or removed, or disinfected.

While an antiseptic agent is not necessarily a disinfectant, all disinfectants are antiseptics; for putrefactive de-

composition is due to the development of "germs" of the same class as that to which disease germs belong, and the agents which destroy the latter also destroy the bacteria of putrefaction, when brought in contact with them in sufficient quantity, or restrain their development when present in smaller amounts.

A large number of the proprietary "disinfectants," so called, which are in the market, are simply deodorizers or antiseptics, of greater or less value, and are entirely untrustworthy for disinfecting purposes.

Antiseptics are to be used at all times when it is impracticable to remove filth from the vicinity of human habitations, but they are a poor substitute for cleanliness.

During the prevalence of epidemic diseases, such as yellow fever, typhoid fever and cholera, it is better to use in privy-vaults, cess-pools, etc., those antiseptics which are also disinfectants—*i. e.*, germicides; and when the contents of such receptacles are known to be infected this becomes imperative.

Still more important is the destruction at our sea-port quarantine stations of infectious material which has its origin outside of the boundaries of the United States, and the destruction, within our boundaries, of infectious material given off from the persons of those attacked with any infectious disease, whether imported or of indigenous origin.

In the sick room we have disease germs at an advantage, for we know where to find them, as well as how to kill them.

Having this knowledge, not to apply it would be criminal negligence, for our efforts to restrict the extension of infectious diseases must depend largely upon the proper use of disinfectants in the sick room.

General Directions.

Disinfection of Excreta, etc.—The infectious character of the dejections of patients suffering from cholera and from typhoid fever is well established; and this is true of mild cases and of the earliest stages of these diseases as well as of severe and fatal cases. It is probable that epidemic

dysentery, tuberculosis, and perhaps diphtheria, yellow fever, scarlet fever and typhus fever may also be transmitted by means of the alvine discharges of the sick. It is therefore of the first importance that these should be disinfected. In cholera, diphtheria, yellow fever and scarlet fever, all vomited material should also be looked upon as infectious. And in tuberculosis, diphtheria, scarlet fever and infectious pneumonia, the sputa of the sick should be disinfected or destroyed by fire. It seems advisable also to treat the urine of patients sick with an infectious disease, with one of the disinfecting solutions below recommended.

Chloride of lime, or bleaching powder, is, perhaps, entitled to the first place for disinfecting excreta, on account of the rapidity of its action. The following standard solution is recommended :

Standard Solution No. 1.

Dissolve Chloride of Lime of the best quality in pure water, in the proportion of four ounces to the gallon.*

Use one quart of this solution for the disinfection of each discharge in cholera, typhoid fever, etc.† Mix well and leave in vessel for at least one hour before throwing into privy vault or water-closet. The same directions apply for the disinfection of vomited matters. Infected sputum should be discharged directly into a cup half full of the solution.

Standard Solution No. 2.

Dissolve Corrosive Sublimate and Permanganate of Potash in pure water, in the proportion of two drachms of each salt to the gallon.

---

*Good chloride of lime should contain at least 25 per cent. of available chlorine. (See *ante*, p. 12.) It may be purchased by the quantity at 3½ cents per pound. The cost of the standard solution recommended is therefore less than one cent a gallon. A clear solution may be obtained by filtration or by decantation, but the insoluble sediment does no harm, and this is an unnecessary refinement.

† For a very copious discharge use a larger quantity. For the disinfection of solid or semi-solid feces use a solution of twice this strength—8 oz. to a gallon of water—in the proportion of 1 quart for every 4 oz. of material to be disinfected.

This is to be used for the same purposes and in the same way as *Standard Solution No. 1*. It is equally effective, but it is necessary to leave it for a longer time in contact with the material to be disinfected—at least four hours. The only advantage which this solution has over the chloride of lime solution consists in the fact that it is odorless, while the odor of chlorine in the sick room is considered by some persons objectionable. The cost is a little more.* It must be remembered that this solution is highly poisonous. It is proper, also, to call attention to the fact that *it will injure lead pipes if passed through them in considerable quantities.*

It will be best to empty the vessel containing excreta and disinfectant into an earthen jar or wooden vessel and to leave it for twenty-four hours, at the end of which time it may be thrown into a privy vault, or into a hole in the ground excavated for this special purpose.

Disinfection of the Person.—The surface of the body of a sick person, or of his attendants, when soiled with infectious discharges, should be at once cleansed with a suitable disinfecting agent. For this purpose solution of chlorinated soda (*liquor sodæ chlorinatæ*) diluted with nine parts of water, or *Standard Solution No. 1* diluted with three parts of water, may be used. A two per cent. solution of carbolic acid is also suitable for this purpose, and under proper supervision the use of a solution of corrosive sublimate—1 : 1000—is to be recommended.

In diseases like small-pox and scarlet fever, in which the infectious agent is given off from the entire surface of the body, occasional ablutions with solution of chlorinated soda diluted with twenty parts of water, will be more suitable than the stronger solution above recommended.

In all infectious diseases the body of THE DEAD should be enveloped in a sheet saturated with *Standard Solution No. 1*, or with a 5 per cent. solution of carbolic acid, or a 1 : 500 solution of corrosive sublimate.

---

* Corrosive sublimate costs about 70 cents a pound, and permanganate of potash 65 cents a pound, by the single pound. This makes the cost of *Standard Solution No. 2* a little more than two cents a gallon.

Disinfection of Clothing.—Boiling for half an hour will destroy the vitality of all known disease germs, and there is no better way of disinfecting clothing or bedding which can be washed than to put it through the ordinary operations of the laundry. No delay should occur, however, between the time of removing soiled clothing from the person or bed of the sick and its immersion in boiling water, or in one of the following solutions; and no article should be permitted to leave the infected room until so treated.

STANDARD SOLUTION NO. 3.

Dissolve four ounces of Corrosive Sublimate and one pound of Sulphate of Copper in a gallon of water.

Two fluid ounces of this standard solution to the gallon of water will make a suitable solution for the disinfection of clothing. The articles to be disinfected must be thoroughly soaked with the disinfecting solution and left in it for at least two hours, after which they may be wrung out and sent to the wash.

N. B. *Solutions of corrosive sublimate should not be placed in metal receptacles*, for the salt is decomposed and the mercury precipitated by contact with copper, lead or tin. A wooden tub or earthen crock is a suitable receptacle for such solutions.

When diluted as directed this solution may be used without danger from poisoning through the medium of clothing immersed in it, or by absorption through the hands in washing. A poisonous dose could scarcely be swallowed by mistake, owing to the metallic taste of the solution, and the considerable quantity which would be required to produce a fatal effect.

Clothing may also be disinfected by immersing it for four hours in a two per cent. solution of carbolic acid.

Clothing or bedding which cannot be washed or subjected to the action of steam, may be disinfected by exposure to dry heat in a properly constructed disinfecting chamber for three or four hours. A temperature of 230° Fah. should be maintained during this time, and the cloth-

ing must be freely exposed—*i. e.*, not folded or arranged in piles or bundles, for the penetrating power of dry heat is very slight.*

The temperature above mentioned will not destroy the *spores* of bacilli—e. g., of the anthrax bacillus, but is effective for the destruction of all disease germs which do not form spores; and there is good reason to believe that this list includes small-pox, cholera, yellow fever, diphtheria, erysipelas, puerperal fever and scarlet fever (?) Moist heat is far more effective, and it is demonstrated that ten minutes exposure to steam, at a temperature of 230° Fah., will destroy all known disease germs, including the most refractory spores.

In the absence of a suitable chamber for the use of dry heat, fumigation with sulphurous acid gas may be resorted to. The room in which disinfection is practiced should be hermetically closed to prevent the escape of the gas, and three pounds of sulphur should be burned in it for every 1000 cubic feet of air space. Expose the articles to be disinfected as freely as possible by hanging them up in the disinfecting chamber, and leave them for at least twelve hours subjected to the action of the sulphurous acid gas.

Soiled mattresses, pillows, feather beds and articles of this nature cannot be effectually disinfected by sulphur fumigation, owing to the fact that the gas does not penetrate to their interior in sufficient amount. For articles of this kind, and in general for articles of little value, which have been soiled by the discharges of the sick, destruction by fire will be advisable.

Disinfection of the Sick Room.—In the sick room no disinfectant can take the place of free ventilation and cleanliness. It is an axiom in sanitary science that *it is impracticable to disinfect an occupied apartment*, for the reason that disease germs are not destroyed by the presence in the atmosphere of any known disinfectant in respirable quantity. Bad odors may be neutralised, but this does

* The limitations with reference to the use of dry heat as a disinfectant are stated in the paper on Dry Heat; see page 107, *ante*.

not constitute disinfection in the sense in which the term is here used. These bad odors are, for the most part, an indication of want of cleanliness, or of proper ventilation; and it is better to turn contaminated air out of the window, or up the chimney, than to attempt to purify it by the use of volatile chemical agents, such as carbolic acid, chlorine, etc., which are all more or less offensive to the sick, and are useless so far as disinfection—properly so called—is concerned.

When an apartment which has been occupied by a person sick with an infectious disease is vacated, it should be disinfected.

The object of disinfection in the sick room is, mainly, the destruction of infectious material attached to surfaces, or deposited as dust upon window-ledges, in crevices, etc. If the room has been properly cleansed and ventilated while still occupied by the sick person, and especially if it was stripped of carpets and unnecessary furniture at the outset of his attack, the difficulties of disinfection will be greatly reduced.

All surfaces should be thoroughly washed with *Standard Solution No.* 1, diluted with three parts of water, or with a 1 : 1000 solution of corrosive sublimate. *Standard Solution No.* 3, diluted in the proportion of four ounces to the gallon of water may be used.

The walls and ceiling, if plastered, should be brushed over with one of these solutions and subsequently washed over with a lime wash.

Especial care must be taken to wash away all dust from window ledges and other places where it may have settled, and to thoroughly cleanse crevices and out-of-the-way places. After this application of the disinfecting solution, and an interval of twenty-four hours or longer for free ventilation, the floors and wood-work should be well scrubbed with soap and hot water, and this should be followed by a second more prolonged exposure to fresh air, admitted through open doors and windows.

As an additional precaution, fumigation with sulphurous acid gas is to be recommended, especially for rooms

which have been occupied by patients with small-pox, scarlet fever, diphtheria, typhus fever and yellow fever. But fumigation with sulphurous acid gas alone, as commonly practiced, cannot be relied upon for disinfection of the sick room and its contents, including bedding, furniture, infected clothing, etc., as is popularly believed.

When fumigation is practiced it should precede the general washing with a disinfecting solution, heretofore recommended.

To ensure any results of value it will be necessary to close the apartment to be disinfected as completely as possible by stopping all apertures through which the gas might escape, and to burn not less than three pounds of sulphur for each thousand cubic feet of air-space in the room. To secure complete combustion of the sulphur it should be placed, in powder or in small fragments, in a shallow iron pan, which should be set upon a couple of bricks in a tub partly filled with water, to guard against fire. The sulphur should be thoroughly moistened with alcohol before igniting it.

Disinfection of privy-vaults, cess-pools, etc. When the excreta (not previously disinfected) of patients with cholera or typhoid fever, have been thrown into a privy vault this is infected and disinfection should be resorted to as soon as the fact is discovered, or whenever there is reasonable suspicion that such is the case. It will be advisable to take the same precautions with reference to privy vaults into which the excreta of yellow fever patients have been thrown, although we do not definitely know that this is infectious material.

The most trustworthy agent for this purpose is corrosive sublimate.

The amount used must be proportioned to the amount of material to be disinfected.

Use one pound of corrosive sublimate for every five hundred pounds (estimated) *of fecal matter contained in the vault.*

Solution No. 3, diluted with three parts of water may be used. The diluted solution should be applied in the

NOTE.—Recent experiments made by Dr. Sternberg (see page 116 *et seq.*) make it apparent that the complete sterilization of large masses of fecal matter in privy vaults would be a difficult and expensive undertaking, if not entirely impracticable. It is therefore of prime importance that infectious material should be destroyed before it is thrown into a receptacle of this kind. But it seems also important that during the prevalence of an epidemic the contents of privy vaults should be rendered unsuitable for the development of disease germs by the use of antiseptics, and that, so far as practicable, infectious material, not previously disinfected, should be destroyed *in situ*. A thorough disinfection of exposed surfaces soiled with the discharges of those who have recently frequented the place and of the exposed surface of the material in the vault is perhaps all that will be accomplished by the use of a solution of the bichloride of mercury as recommended. But it is doubtful whether more would be accomplished by the use of any other disinfectant, in reasonable quantity, and the superior potency of the bichloride as a germicide and antiseptic seems to the committee to justify the recommendation made with reference to its use in privy vaults. The liberal use of a good disinfecting powder upon the surface of such masses of organic material is also to be commended, and for this purpose chloride of lime diluted with some inert substance, on the score of economy and efficiency, is perhaps the most useful agent. (See p. 64).

proportion of one gallon to every four gallons (estimated) of the contents of the vault.

All exposed portions of the vault, and the wood-work above it, should be thoroughly washed down with the disinfecting solution.

To keep a privy vault disinfected during the progress of an epidemic, sprinkle chloride of lime freely over the surface of its contents daily. Or if the odor of chlorine is objectionable, apply daily four or five gallons of *Standard Solution No. 2*, which should be made up by the barrel, and kept in a convenient location, for this purpose.

Disinfection of ingesta.—It is well established that cholera and typhoid fever, are very frequently, and perhaps usually, transmitted through the medium of infected water or articles of food, and especially milk. Fortunately we have a simple means at hand for disinfecting such infected fluids. This consists in the application of heat. *The boiling temperature maintained for half an hour kills all known disease germs.* So far as the germs of cholera, yellow fever, and diphtheria are concerned, there is good reason to believe that a temperature considerably below the boiling point of water will destroy them. But in order to keep on the safe side it is best not to trust anything short of the boiling point (212°F.) when the object is to disinfect food or drink which is open to the suspicion of containing the germs of any infectious disease.

During the prevalence of an epidemic of cholera it is well to boil all water for drinking purposes. After boiling, the water may be filtered, if necessary to remove sediment, and then cooled with *pure* ice if desired.

George M. Sternberg.
Joseph H. Raymond.
Charles Smart.
Victor C. Vaughan.
A. R. Leeds.
W. H. Watkins.
George H. Rohé.